Module Assembly in ALICE ITS Upgrade

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Outline

- Motivation
- Concept Design of ALICE/ITS Module Assembly
- Conclusion and Outlook

Motivation

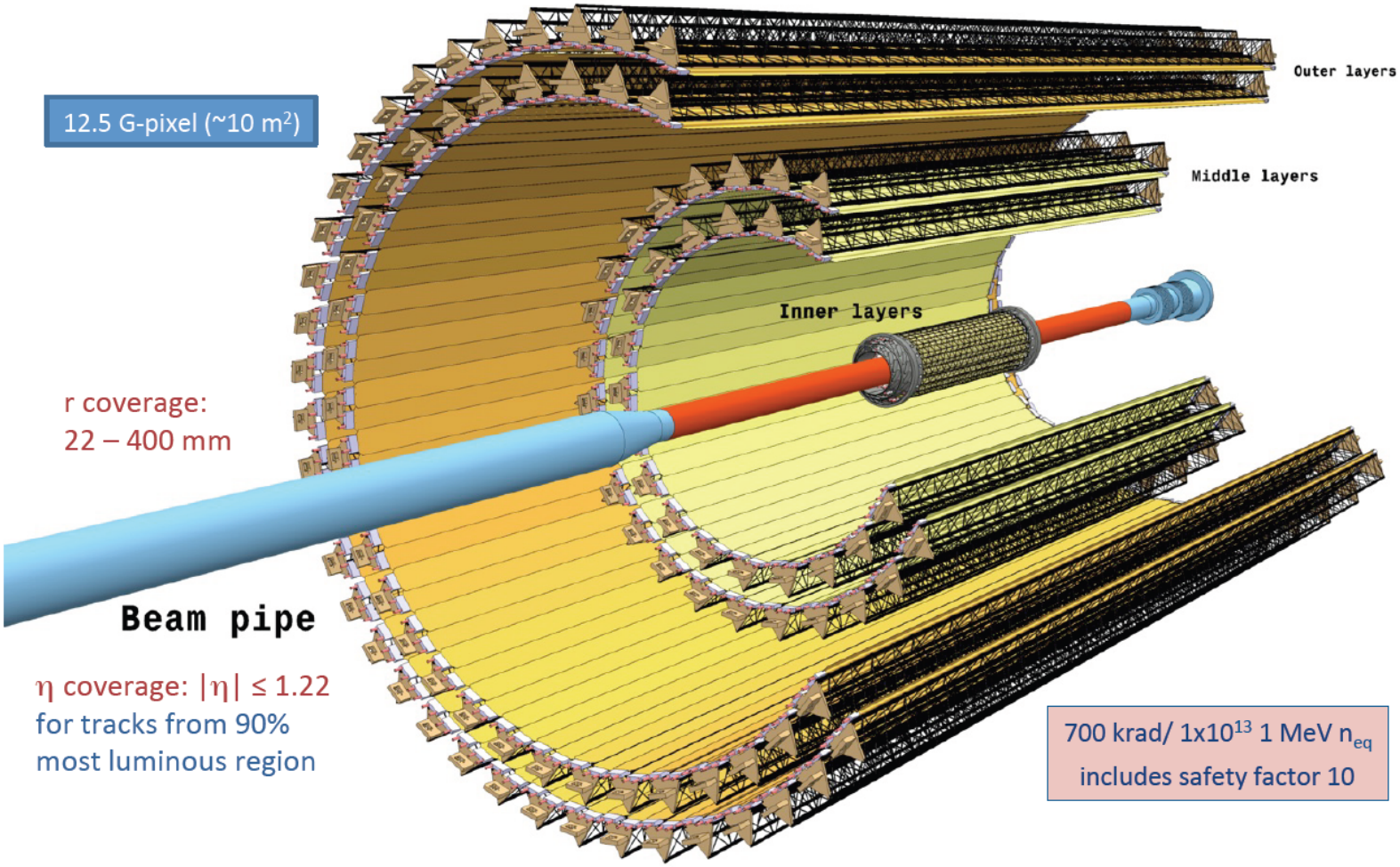
- Contribute to ALICE ITS upgrade project, targeting at heavy flavor physics
- Learn high precision and automatic assembly technique and transfer it to PLAC/HFEE applications

Following contents are mostly from V. Manzari (Bari/INFN) and A. Di Mauro (CERN)'s talks at "4th ALICE ITS upgrade, MFT and O^2 Asian Workshop 2014@Pusan"

Concept Design of ALICE/ITS Module Assembly

Detector Layout Overview

7 layers of Monolithic Active Pixel Sensors



12.5 G-pixel (~10 m^2)

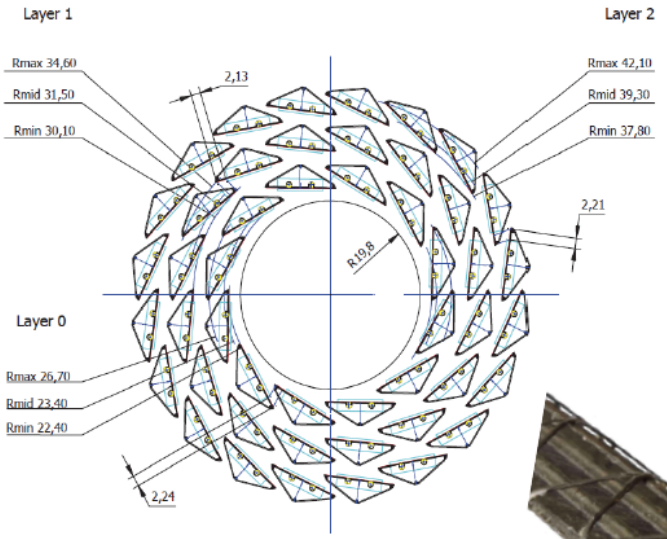
r coverage:
22 – 400 mm

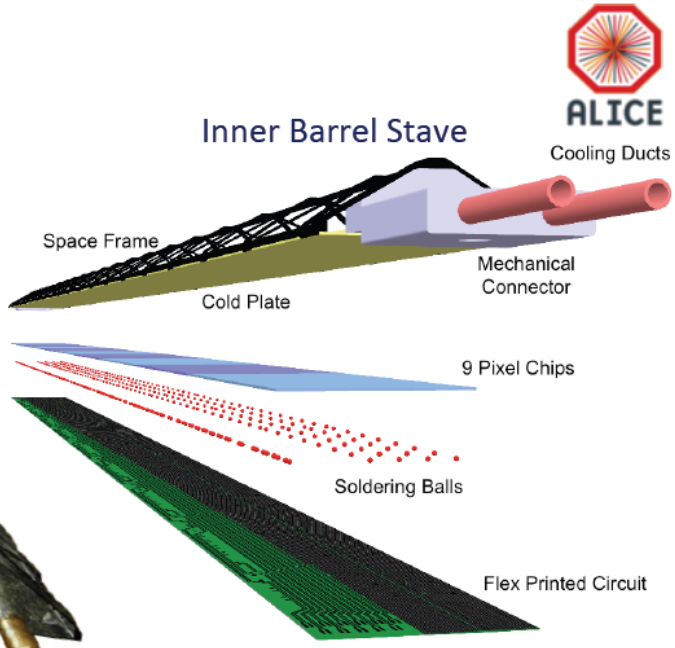
η coverage: $|\eta| \leq 1.22$
for tracks from 90%
most luminous region

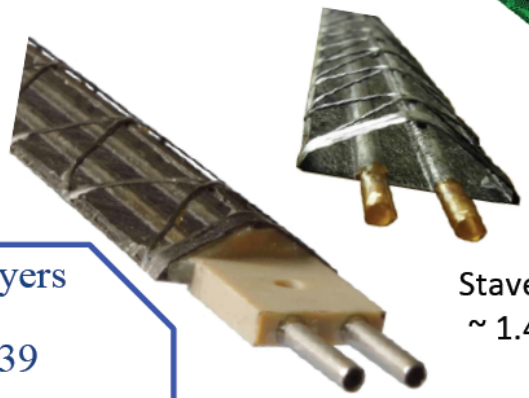
700 krad/ $1x10^{13}$ 1 MeV n_{eq}
includes safety factor 10

Concept Design of ALICE/ITS Module Assembly

Inner Barrel







Inner Barrel (IB): 3 Inner Layers

Radial position (mm): 23, 31, 39

Length in z (mm): 271

Nr. of staves: 12, 16, 20

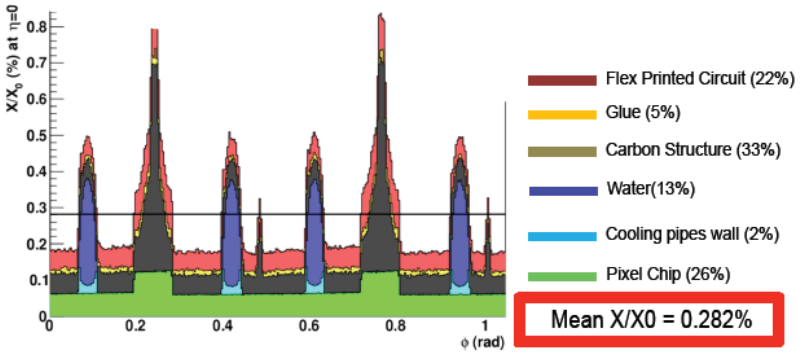
Nr. of modules/stave: 1

Nr. of chips/module: 9

Nr. of chips/layer: 108, 144, 180

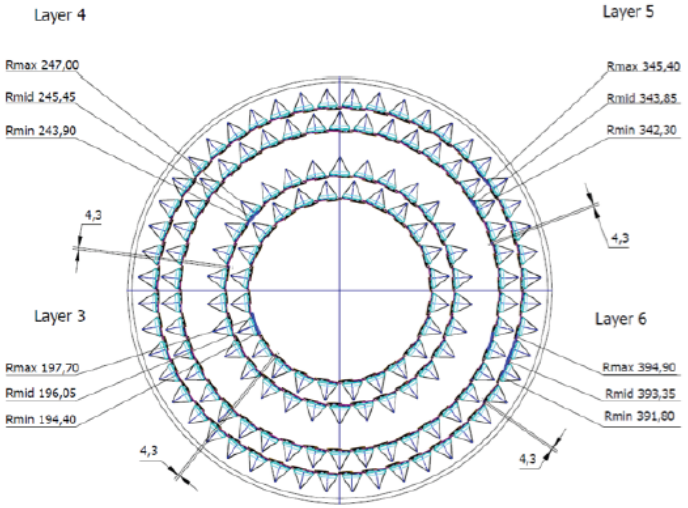
Material thickness: ≤ 0.3% X_0 per layer

Stave weight
~ 1.4 grams

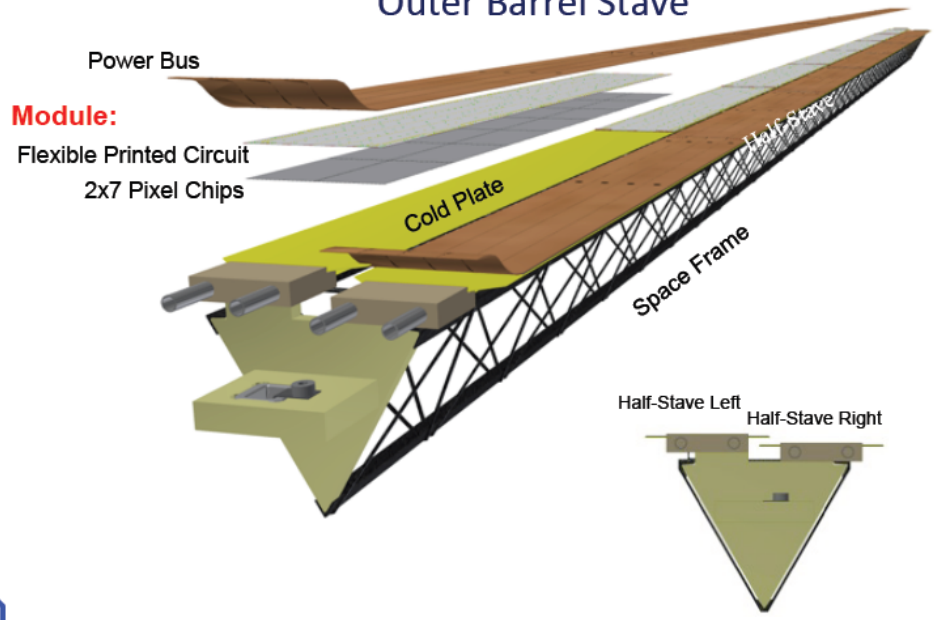


Concept Design of ALICE/ITS Module Assembly

Outer Barrel



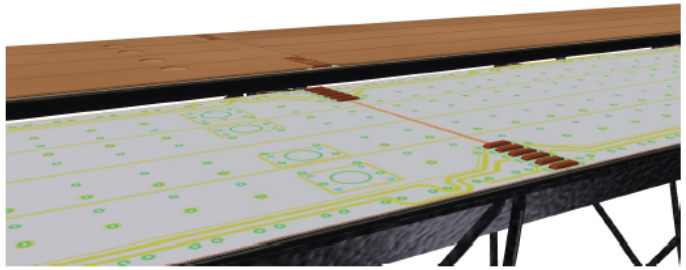
Outer Barrel Stave



Outer Barrel (OB): 2 ML + 2 OL

Radial position (mm): 196, 245, 344, 393
Length in z (mm): 843, 1475
Nr. of staves: 24, 30, 42, 48
Nr. of half-staves/stave: 2
Nr. of modules/half-stave: 4 (ML), 7 (OL)
Nr. of chips/module: 14
Nr. of chips/layer: 2688, 3360, 8232, 9408
Material thickness: ~ 1% X_0 per layer

Module to Module and Power Bus connections



No. of modules and interconnections:

- Some redundancy in the quantity of modules to be produced is required, specifically 120% for the IB, 20% for the OB, resulting in a total 2136 Hybrid Integrated Circuits (HICs); more specifically:

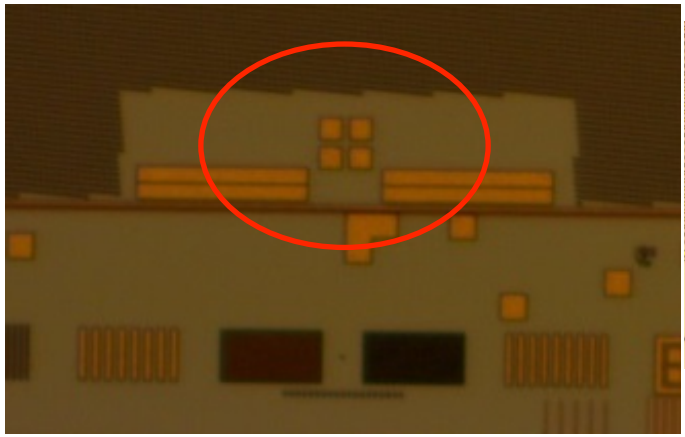
  - IB: n. 106 "*9-chips*" HICs (954 chips to be soldered)
  - OB: n. 2030 "*14-chips*" HICs (28420 chips to be soldered)

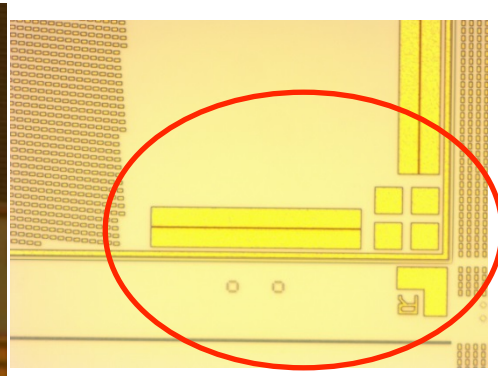
- Considering ~ 80 pads/chip → ~ 2.4 M interconnections

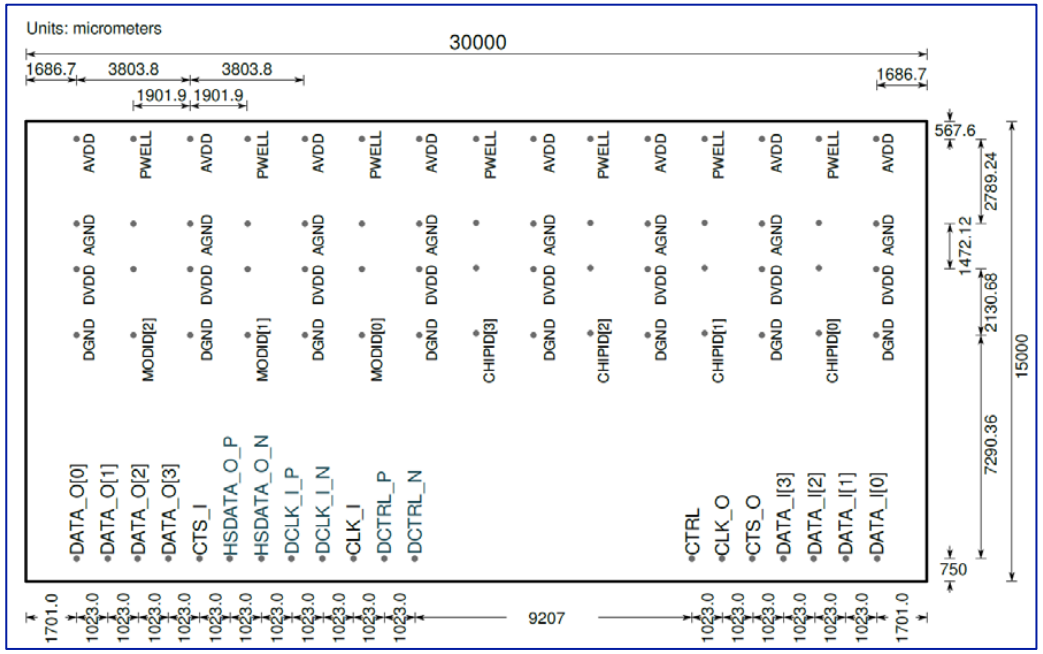
Concept Design of ALICE/ITS Module Assembly

Silicon chip main characteristics:

- 30x15 mm silicon chip, thinned to 50± 5 µm; dicing tolerance -0/+30 µm
- Contact pads are in aluminium, coated by Ni/Au, 300 µm diameter
- Reference targets at the four corners and along the edges
- Chips warp ~ 0.5 mm



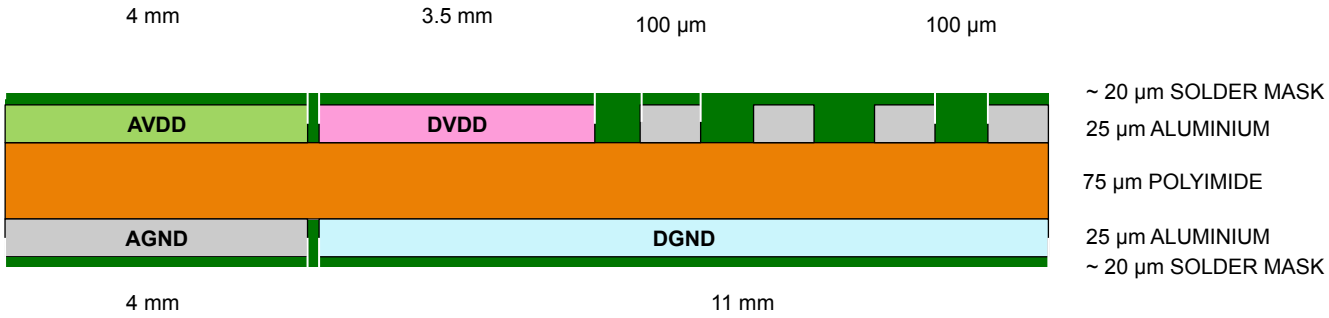


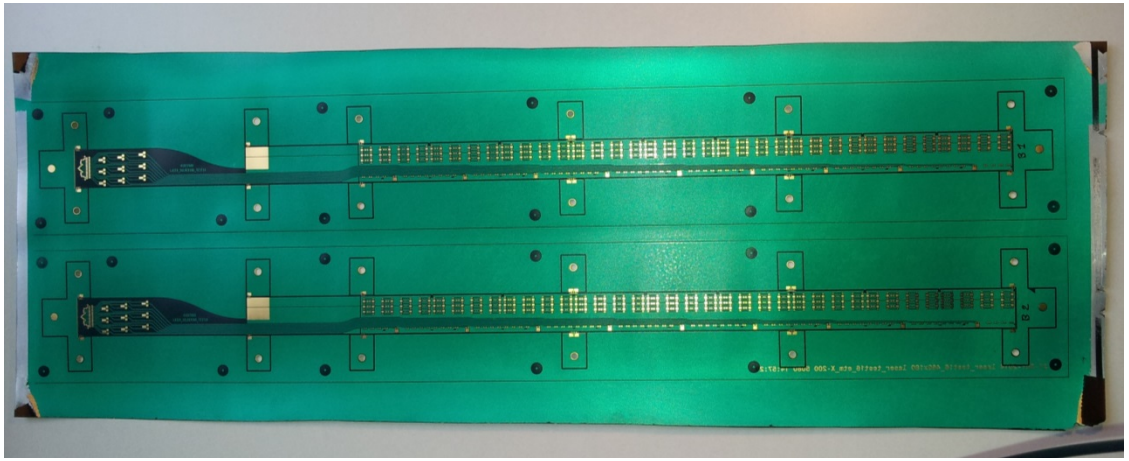


Concept Design of ALICE/ITS Module Assembly

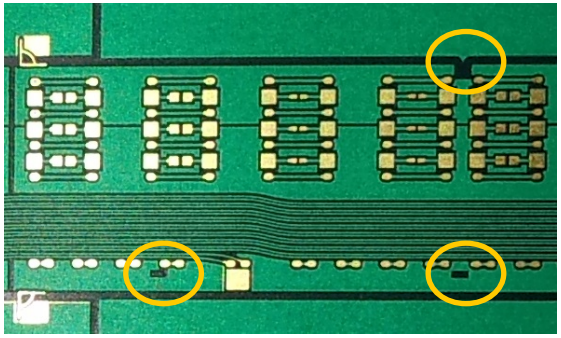
FPC main characteristics:

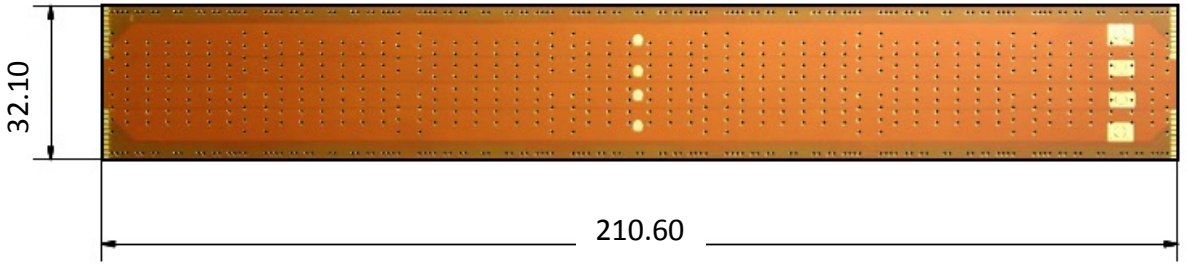
- 3 layouts:
  - IB: 1x9 chips, Al
  - OB: 2x7 chips, Cu
  - MFT: 1x1, 1x2,…, 1x5 chips , Al
- Metallised vias of 220 µm diameter
- Two openings of 1x1 and 1x0.4 mm^2, respectively, to "see" chip targets





IB

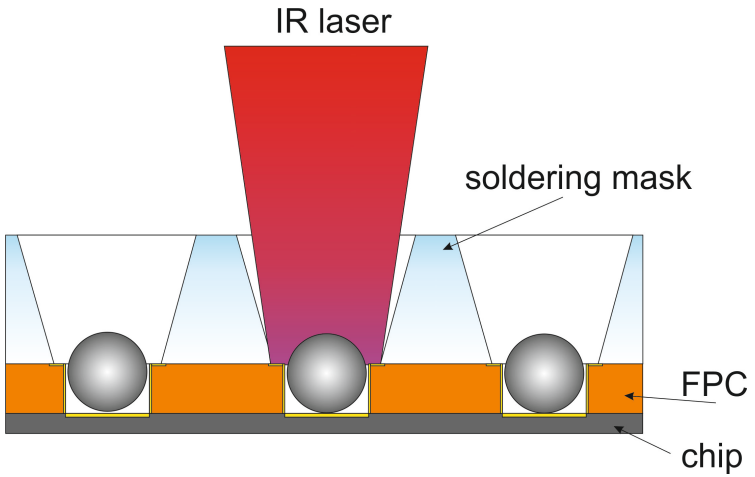




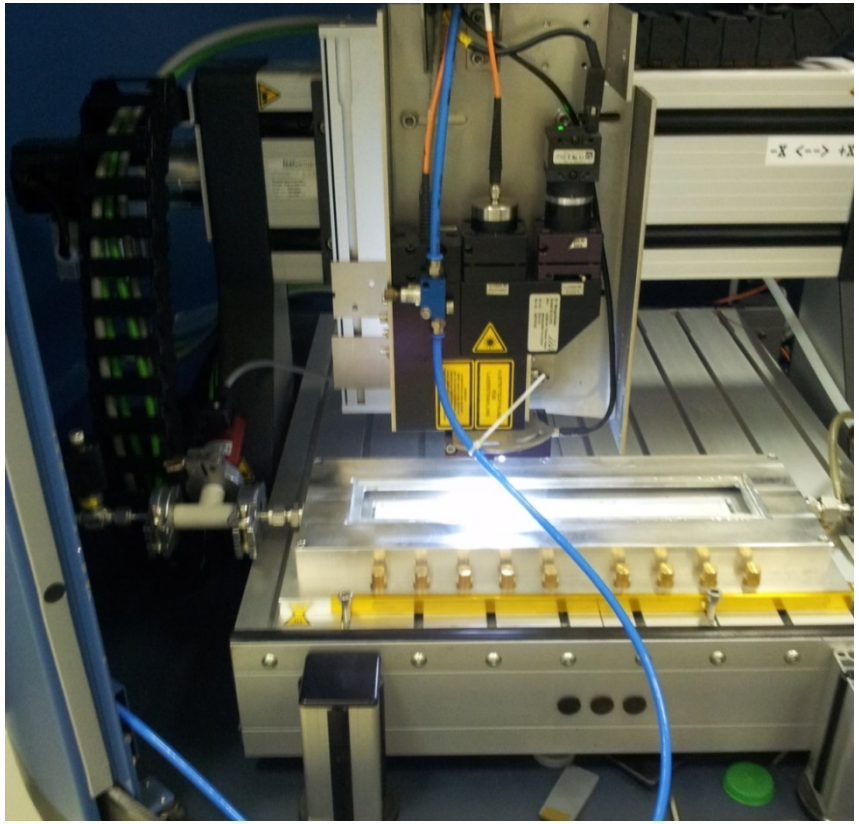
OB

Concept Design of ALICE/ITS Module Assembly

Laser soldering main characteristics:

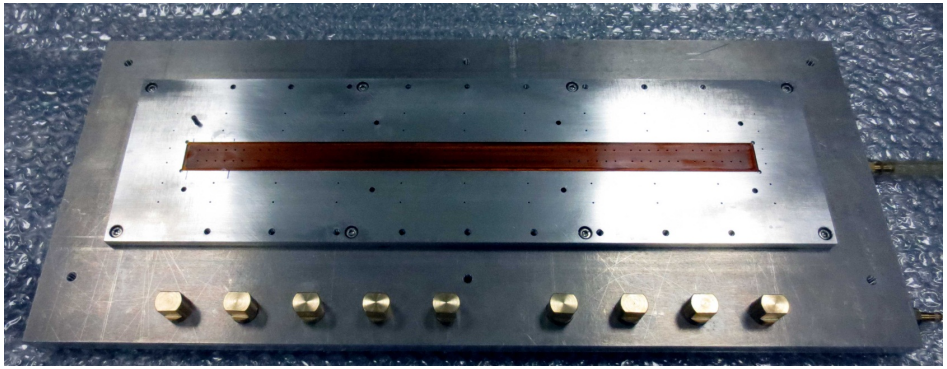


- Interconnection between FPC and chip by fluxless laser soldering of 200 µm diameter Sn/Ag(96.5/3.5) balls (227 ^{o}C melting T) in vacuum ($\leq 10^{-1}$ mbar)
- IR diode laser, 976 nm, 25 W, 50 mm focal length, 0.25 mm beam spot size
- Laser power modulated by pyrometer (LASCON ® system supplied by Dr. Mergenthaler GMBH & CO), programmable T profile ensures precise limitation of heating
- Soldering mask (in Macor® or Rubalit ®) used to push FPC on chip and guide soldering balls inside FPC vias

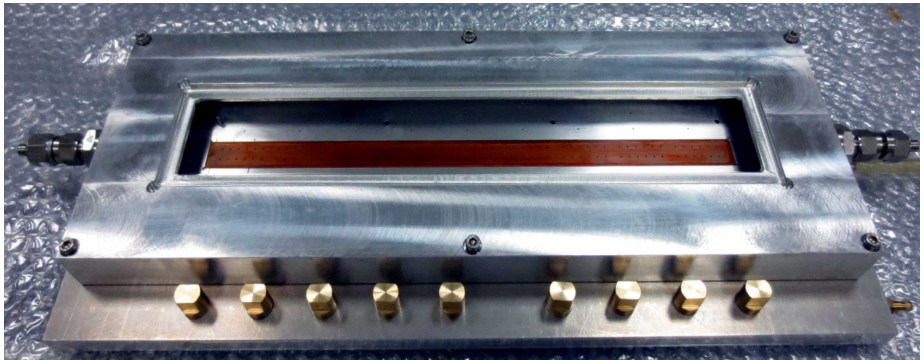


Tooling for the module assembly: IB work table

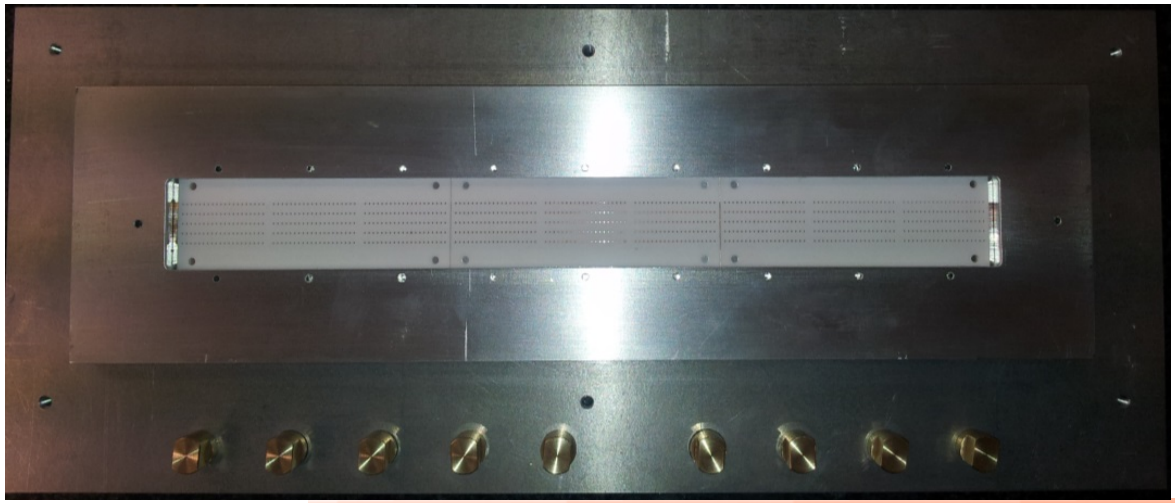
The chips vacuum chuck



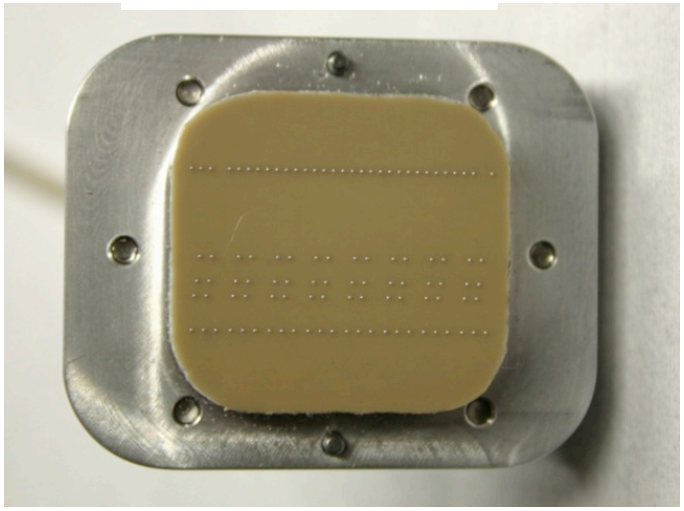
Vacuum lid with quartz window



The soldering mask

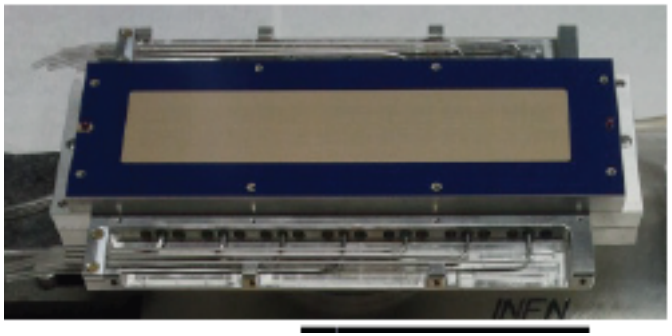


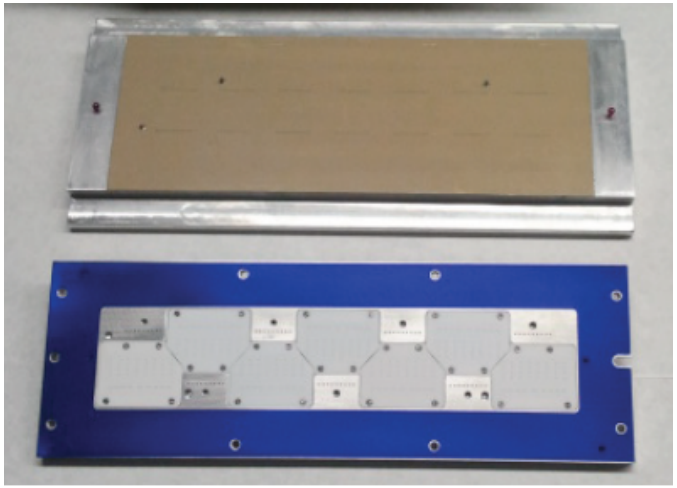
Ball transfer tool

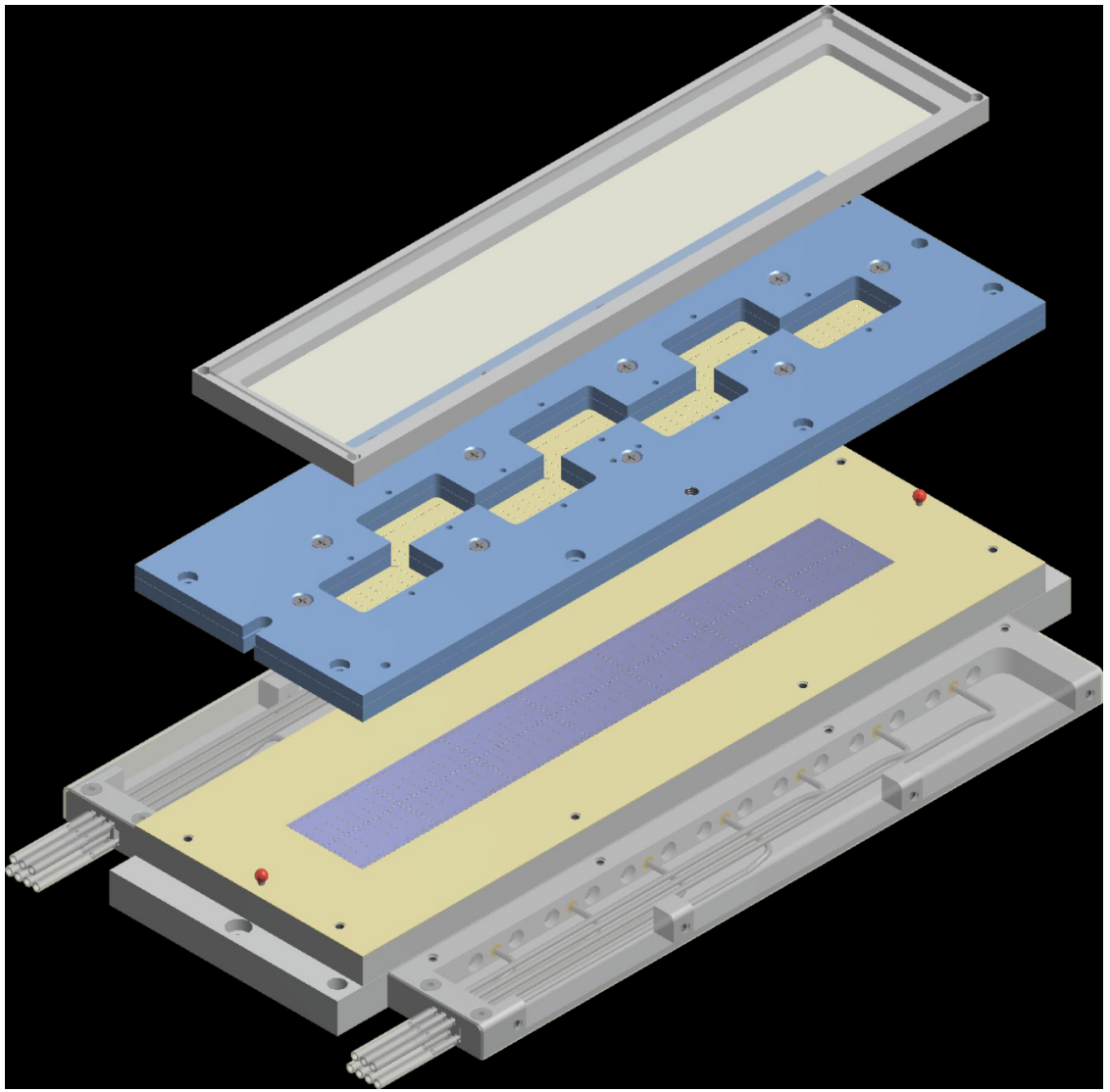


Concept Design of ALICE/ITS Module Assembly

Tooling for the module assembly: OB work table







Concept Design of ALICE/ITS Module Assembly

Accuracy required to the module assembly:

- Presently, final accuracy of FPC hole position not yet known:
  - IB: Al FPC ~ 50 µm (hope to improve it)
  - OB: Cu FPC ~ 20 µm
- The 300 µm pad can compensate hole position variations up to ± 40 µm
- The 100 µm gap between chips seal ring, with the present dicing accuracy, translates in a physical gap between chip edges of ~ 40-50 µm (if needed it could be increased)
- A chip placement accuracy of ± 5 µm is a very tight and conservative requirement to prevent issues related to FPC/chip alignment

Key aspects of the module assembly:

- The amount of modules and the time available require a distributed production over 6 sites (Bari/Italy, CERN, Liverpool/UK, Pusan/Korea, Strasbourg/France, Wuhan/China).
- Usage of same procedure and system is necessary to ensure homogenous production
- To simplify/shorten the assembly procedure, chips are placed in nominal positions and FPC is overlapped using nominal pinholes

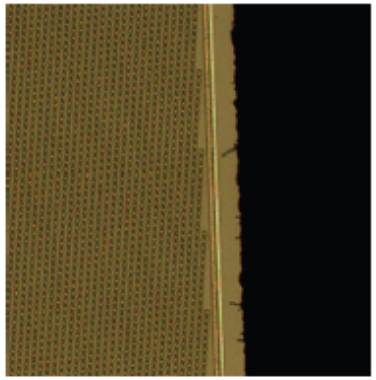
Baseline module assembly system:

- Semi-automatic placement of chips on flat vacuum chuck: operator moves chips from pallet using a console, placement assisted by vision system, inter-chip gap (from seal-ring) of 100 µm, required position tolerance of ± 5 µm at 3σ with respect to reference targets on assembly table
- Stack of FPC + soldering mask placed manually by operator on top of chips
- Distribution of 200 µm soldering balls inside mask holes by operator
- Mounting of lid with quartz window and start of vacuum pump by operator
- Automatic laser soldering of each interconnection; X,Y positioning accuracy: ± 30 µm. Three different modes of operations:
  - fully manual by console; this mode is used for testing purposes and laser beam focusing optimization;
  - programmable in X,Y, providing coordinates either as keyboard input or from a file;
  - fully automated, centred in FPC holes recognized by the vision system.

Concept Design of ALICE/ITS Module Assembly

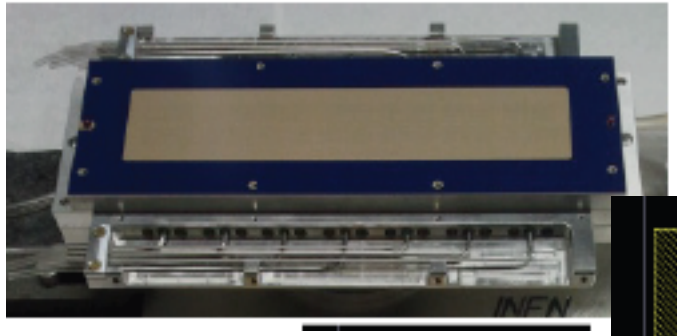
Module assembly procedures:

1. Chip visual inspection – dimensions, warp, integrity, cleanness



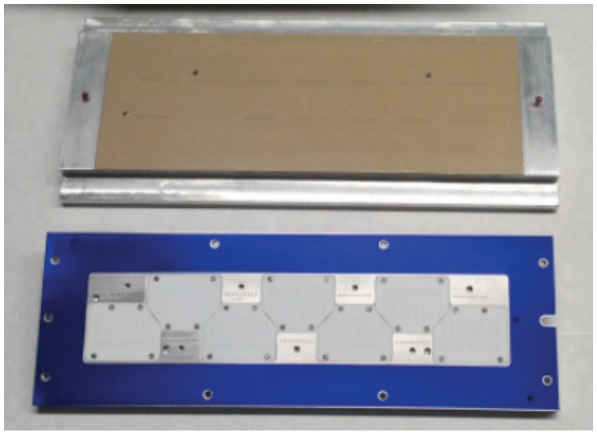
2. Chip placement/alignment – pick up from the chip pallet and place above a vacuum chunk in nominal position w.r.t. reference point

- 9 (14) chips one by one
- Use reference markers on chip surface and vacuum chuck
- Gap beween adjacent chips:
  - ☑ 100 um between nominal edge
  - ☑ 200 um between center of cross reference makers



Module assembly procedures:

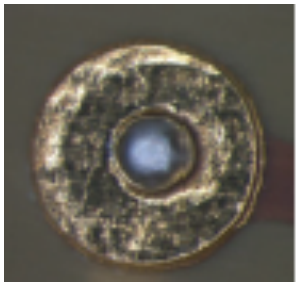
3. FPC placement/alignment – placement above the chips array in nominal position using a jig embedding a soldering mask.

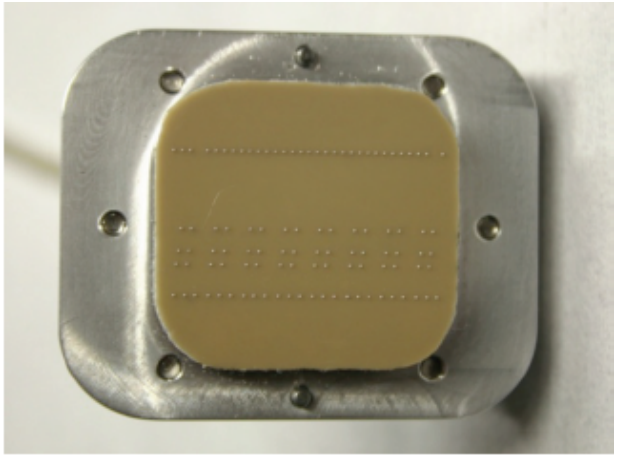


- Use locating pinholes and ruby spheres
- The soldering mask is a ceramic plate with 0.5 mm holes corresponding to the FPC vias
- The jig gently press the FPC against the pixel chips to minimize the gap between them

4. Soldering balls placement – fill the soldering mask holes with the soldering balls using the ball transfer tool

- The soldering mask guides the soldering balls into the FPC vias
- One chip at a time, use pinholes for alignment
- Visual inspection to ensure each hole if filled one and only one soldering ball

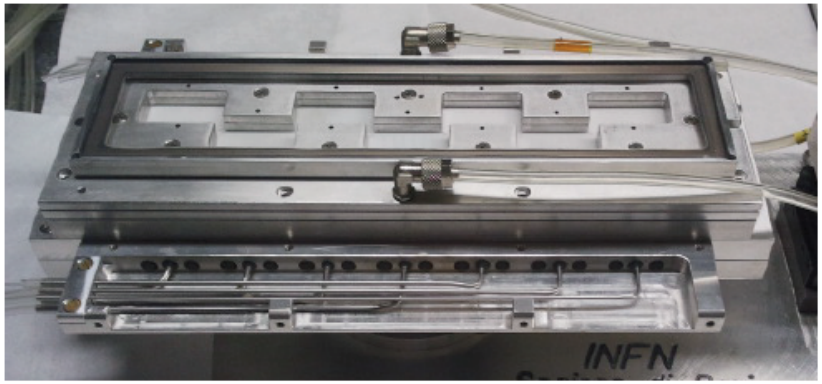




Module assembly procedures:

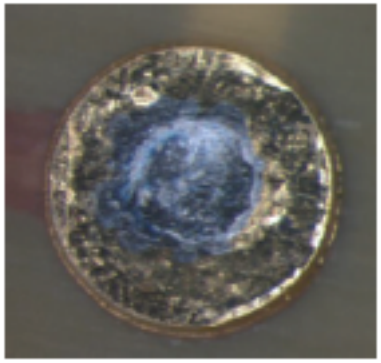
5. Soldering readiness – install the vacuum tight lid equipped with the quartz window above the pixel chips, FPC and soldering mask stack-up

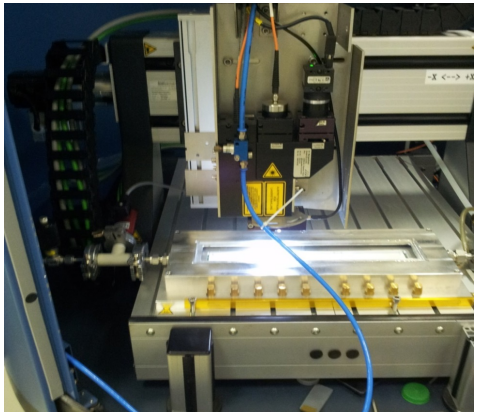
- Start vacuum pump to empty the soldering volume till ready for laser soldering
- Pressure of the chip vacuum chuck always smaller than the soldering volume



6. Laser soldering – shoot laser through the quartz window onto each soldering balls in sequence to melt them and establish the connection between FPC and chip

- Visual checks of soldering joints

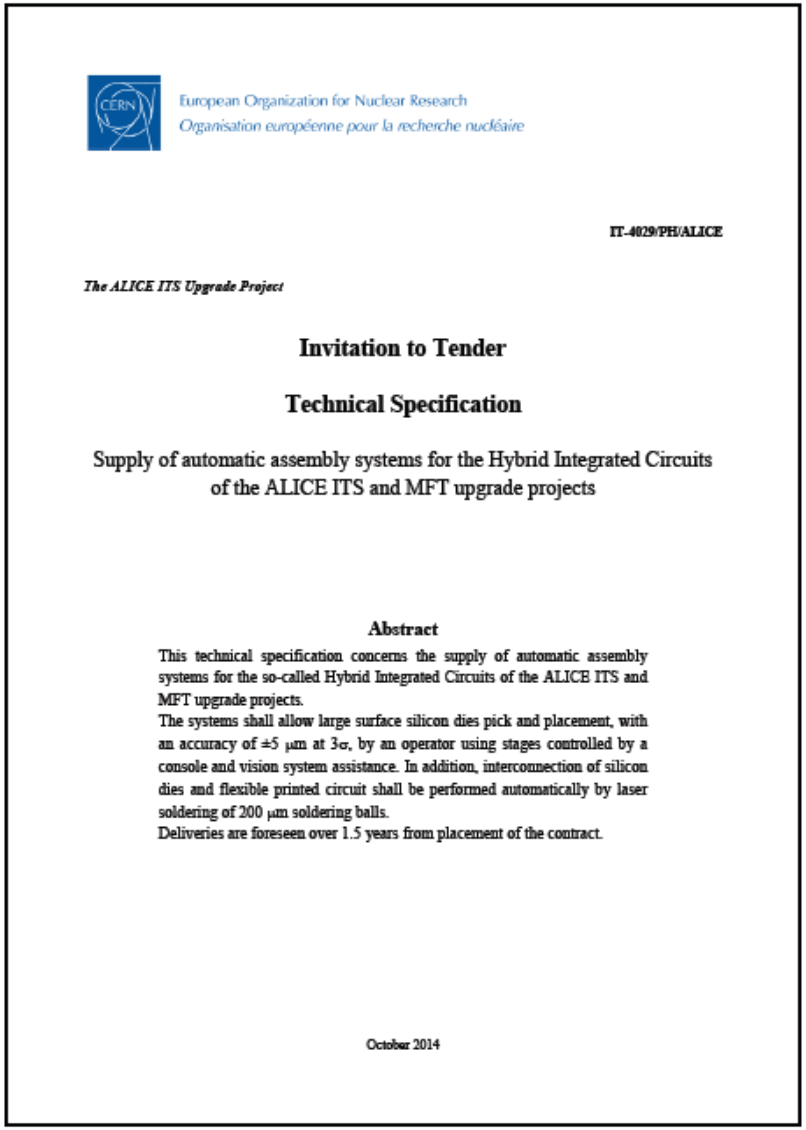




Concept Design of ALICE/ITS Module Assembly

OB module construction:

- Procurement of the automatic assembly systems is centrally managed by the project with a tendering launched from CERN.



European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

IT-4029/PH/ALICE

The ALICE ITS Upgrade Project

Invitation to Tender

Technical Specification

Supply of automatic assembly systems for the Hybrid Integrated Circuits of the ALICE ITS and MFT upgrade projects

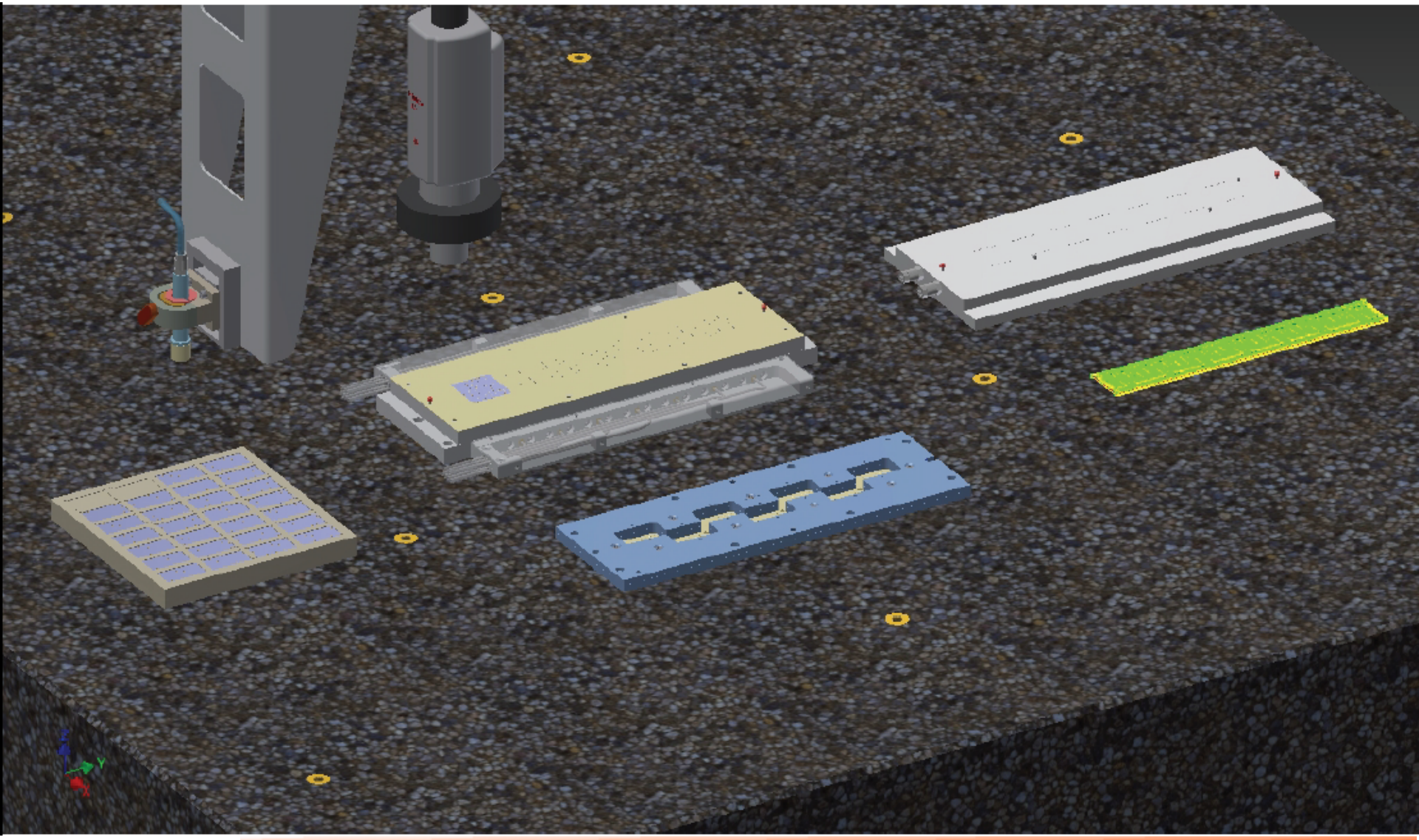
Abstract

This technical specification concerns the supply of automatic assembly systems for the so-called Hybrid Integrated Circuits of the ALICE ITS and MFT upgrade projects.
The systems shall allow large surface silicon dies pick and placement, with an accuracy of ±5 μm at 3σ, by an operator using stages controlled by a console and vision system assistance. In addition, interconnection of silicon dies and flexible printed circuit shall be performed automatically by laser soldering of 200 μm soldering balls.
Deliveries are foreseen over 1.5 years from placement of the contract.

October 2014

Concept Design of ALICE/ITS Module Assembly

Assembly cartoon with automatic module assembly machine:



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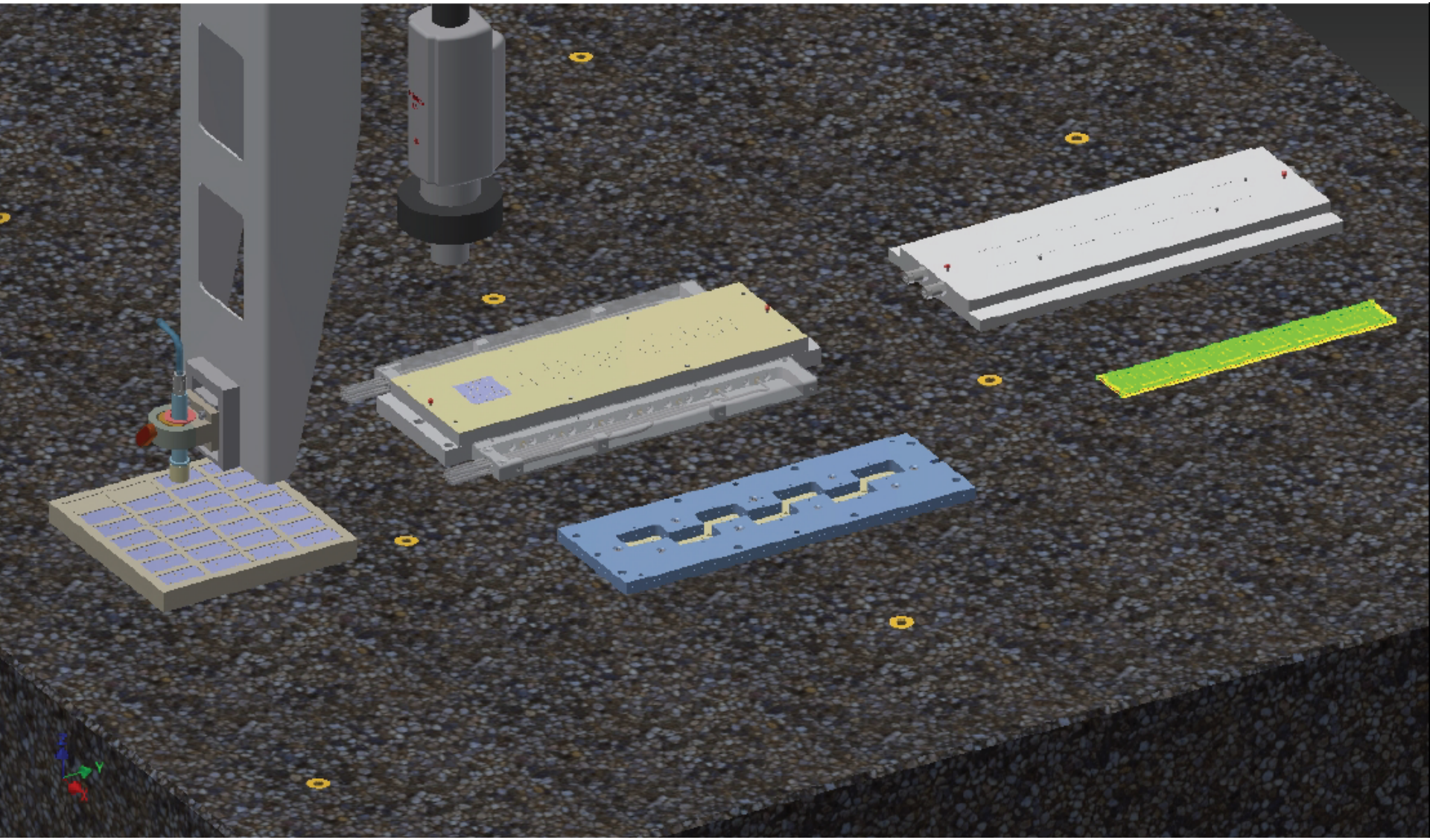

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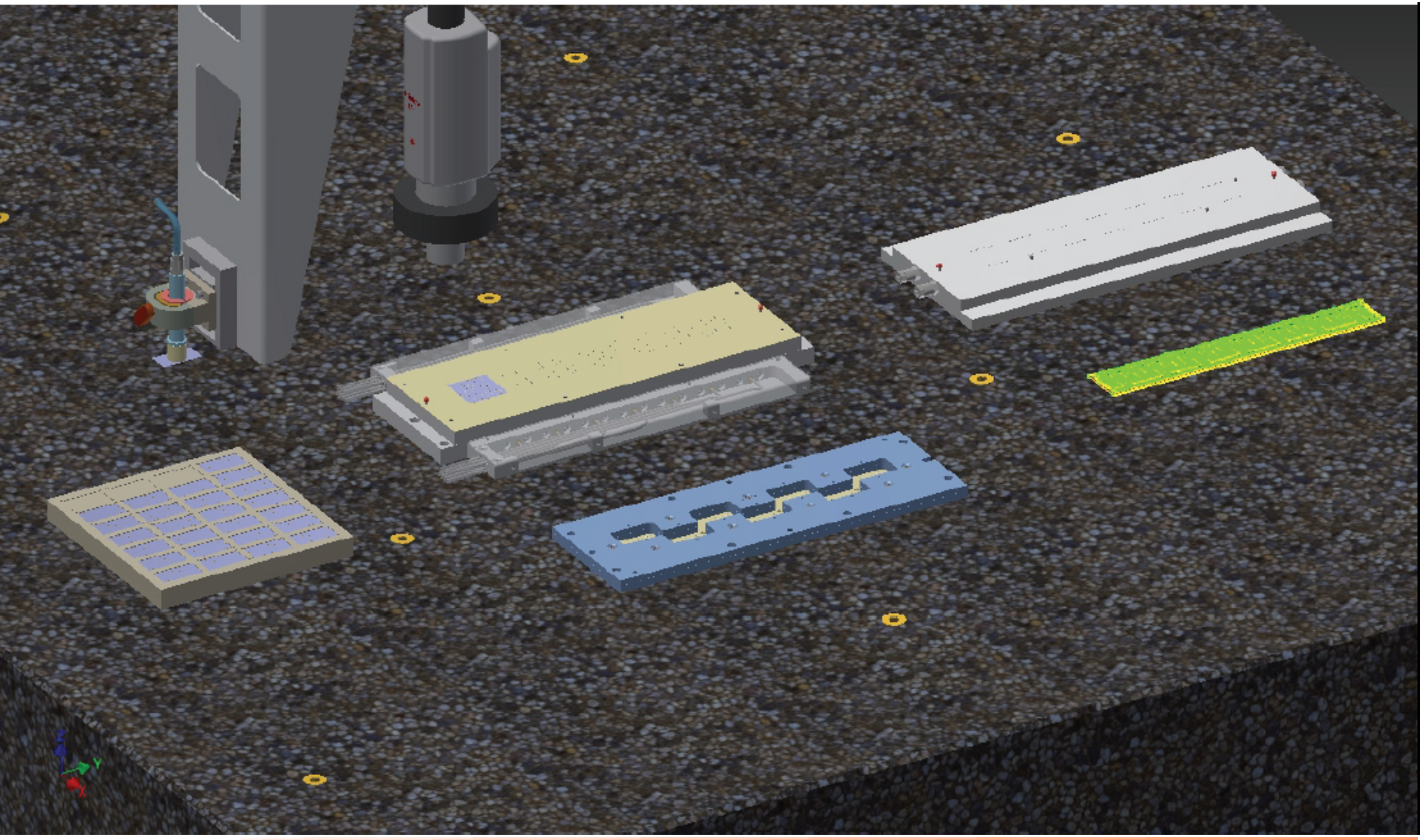

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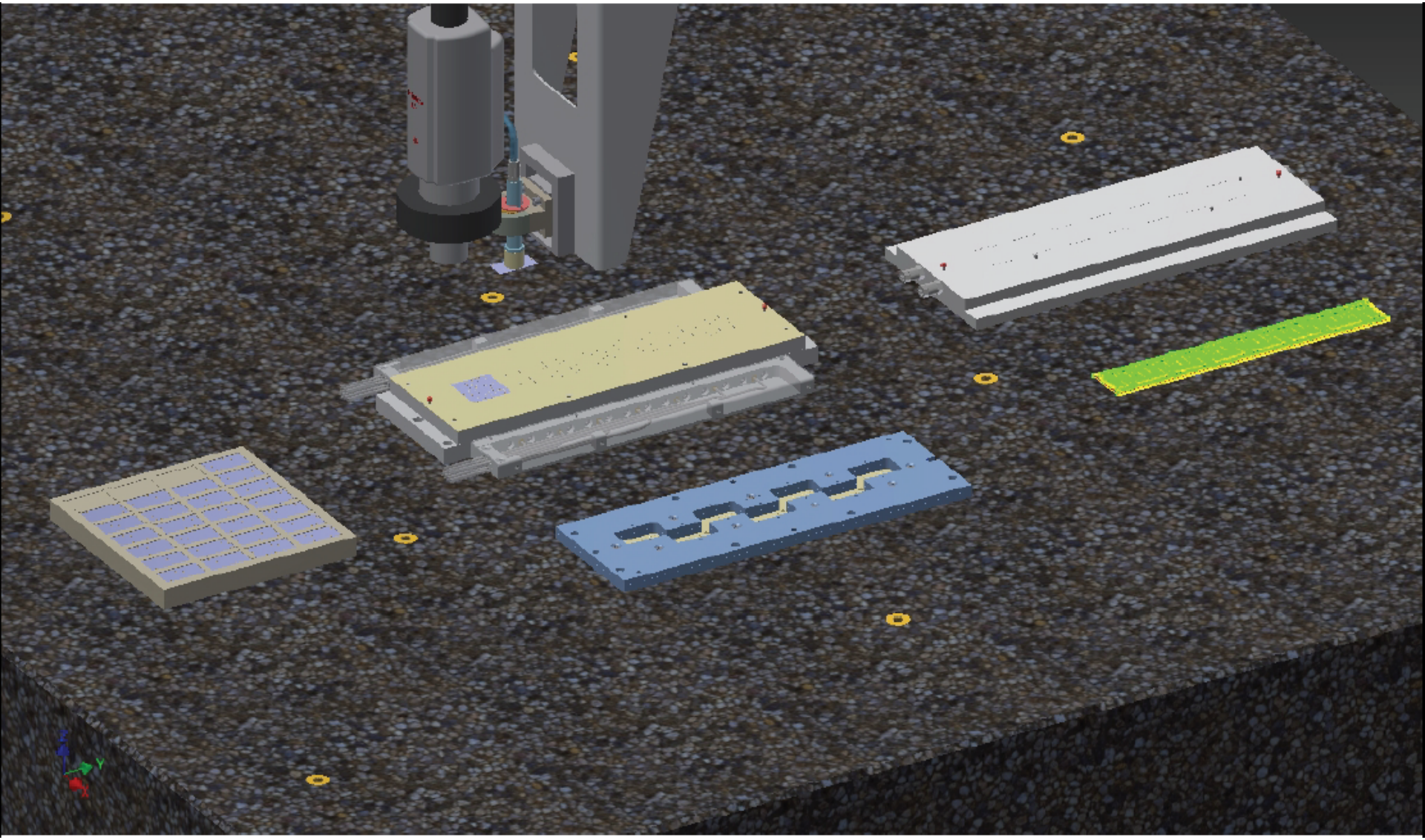

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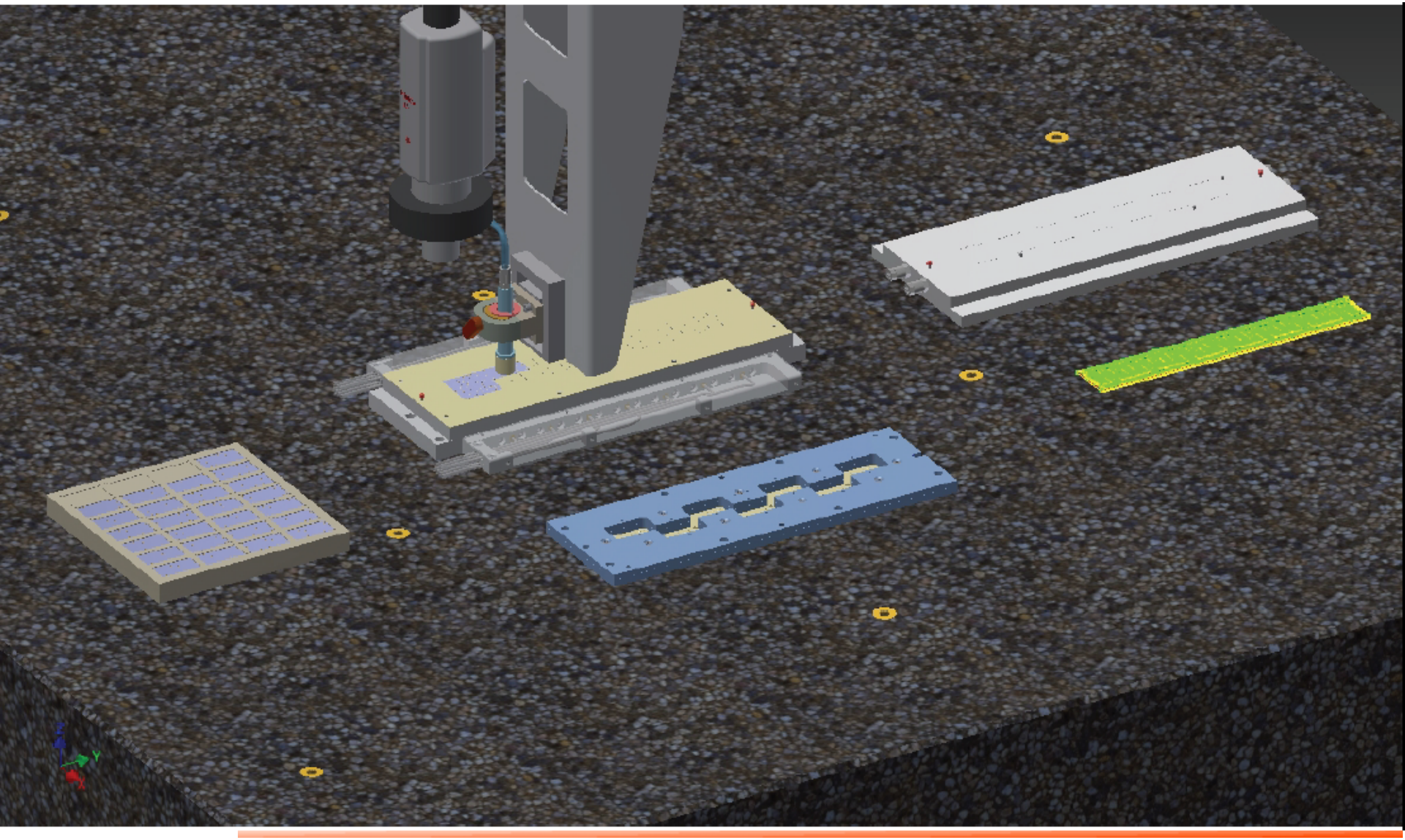

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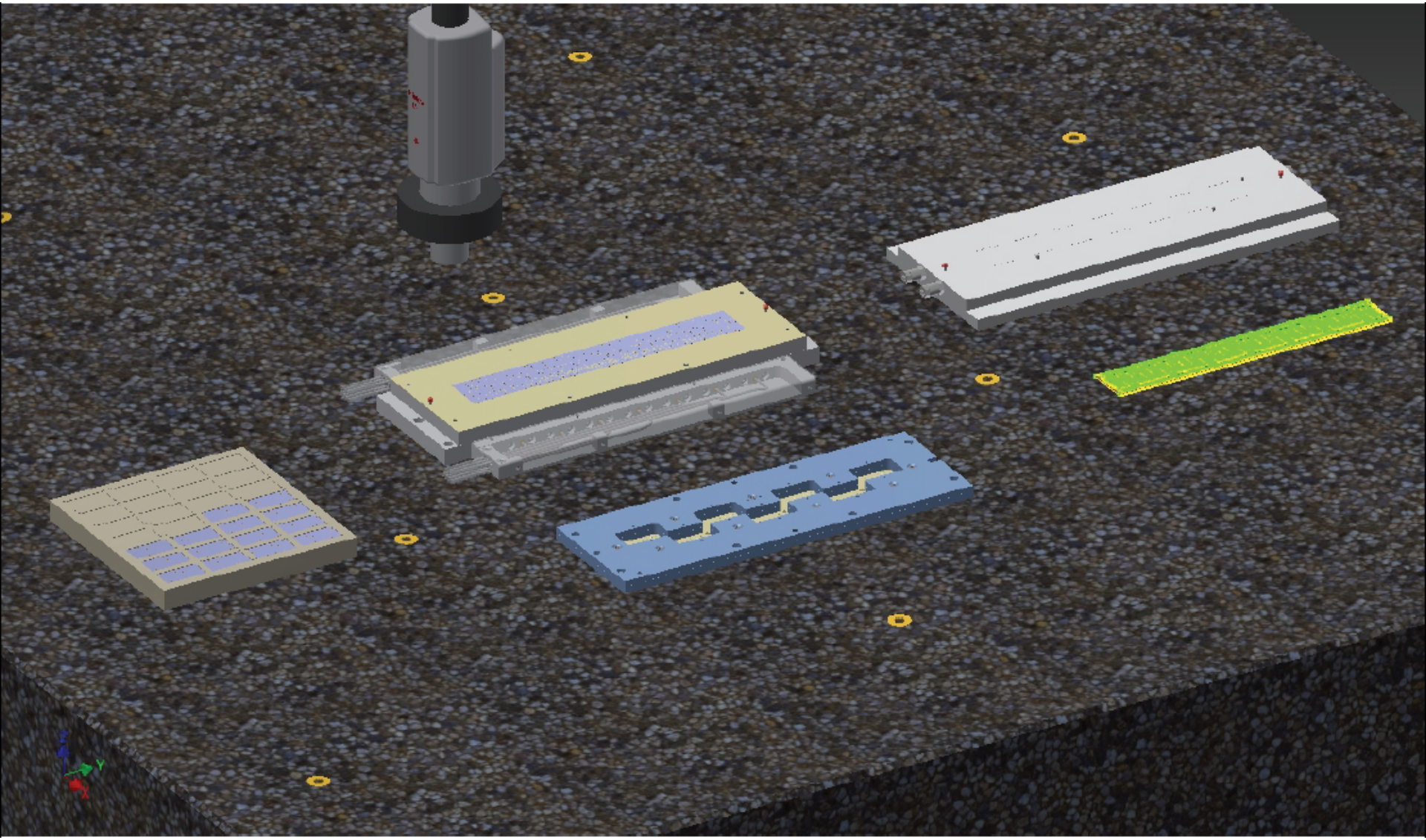

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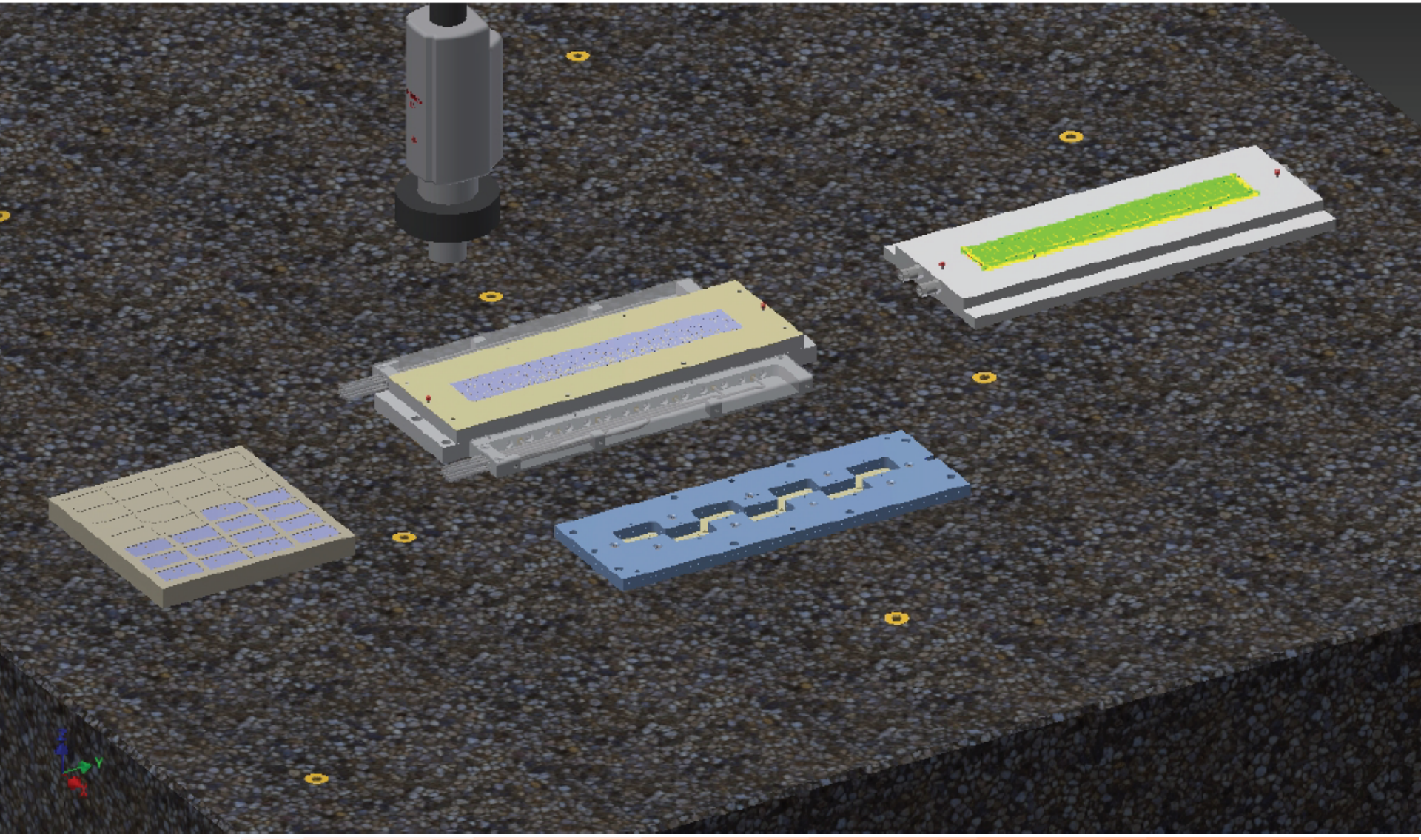

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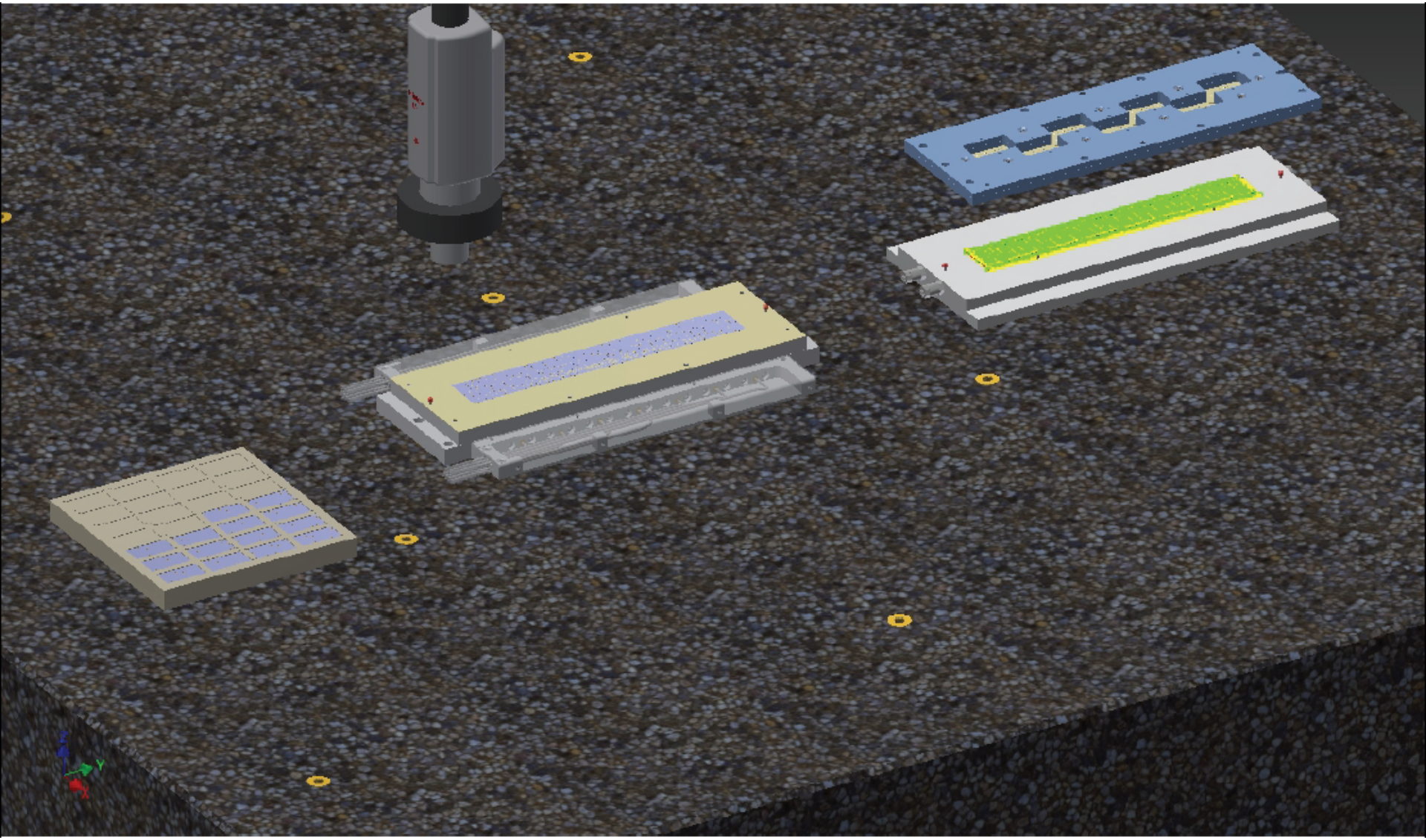

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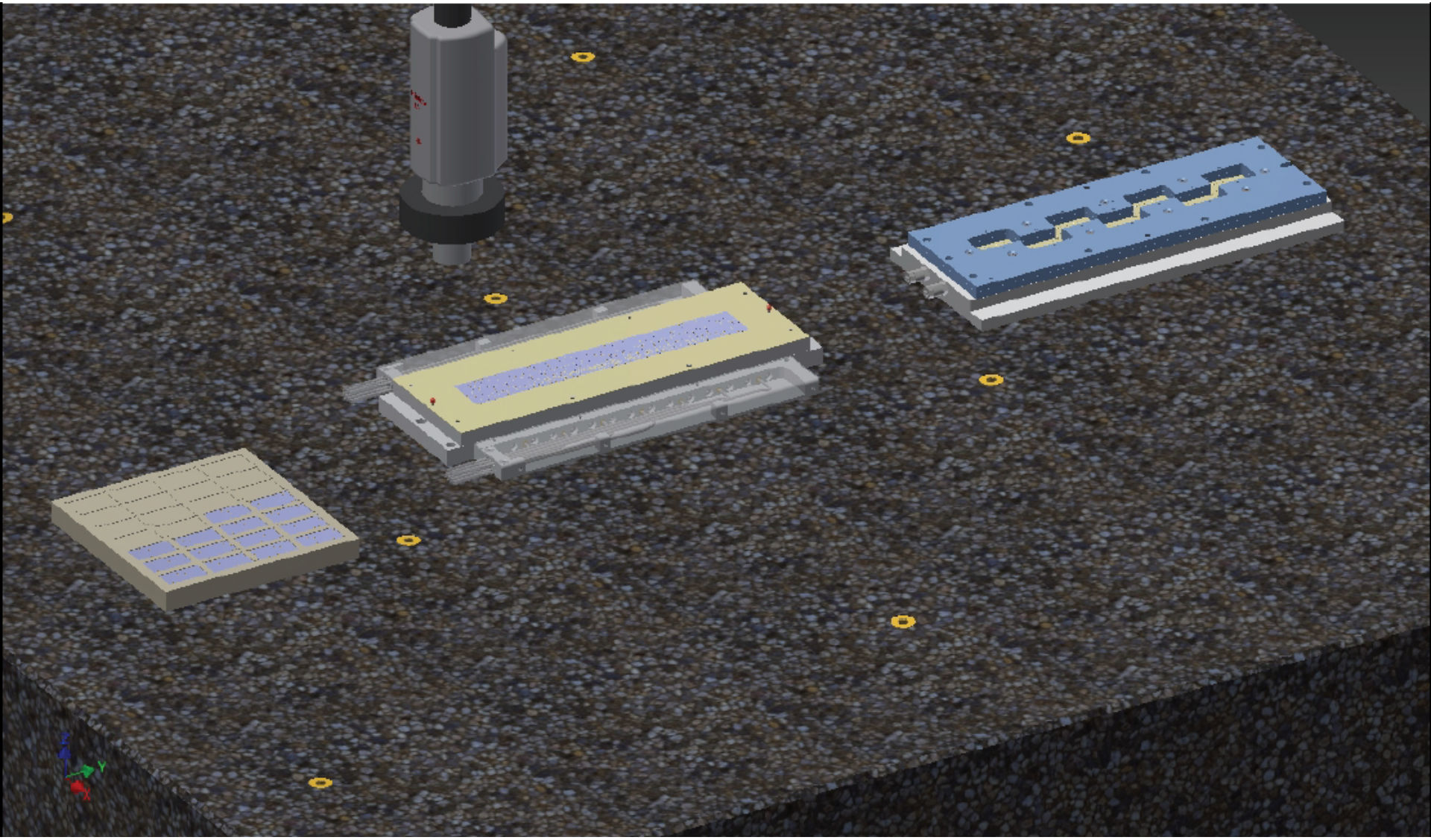

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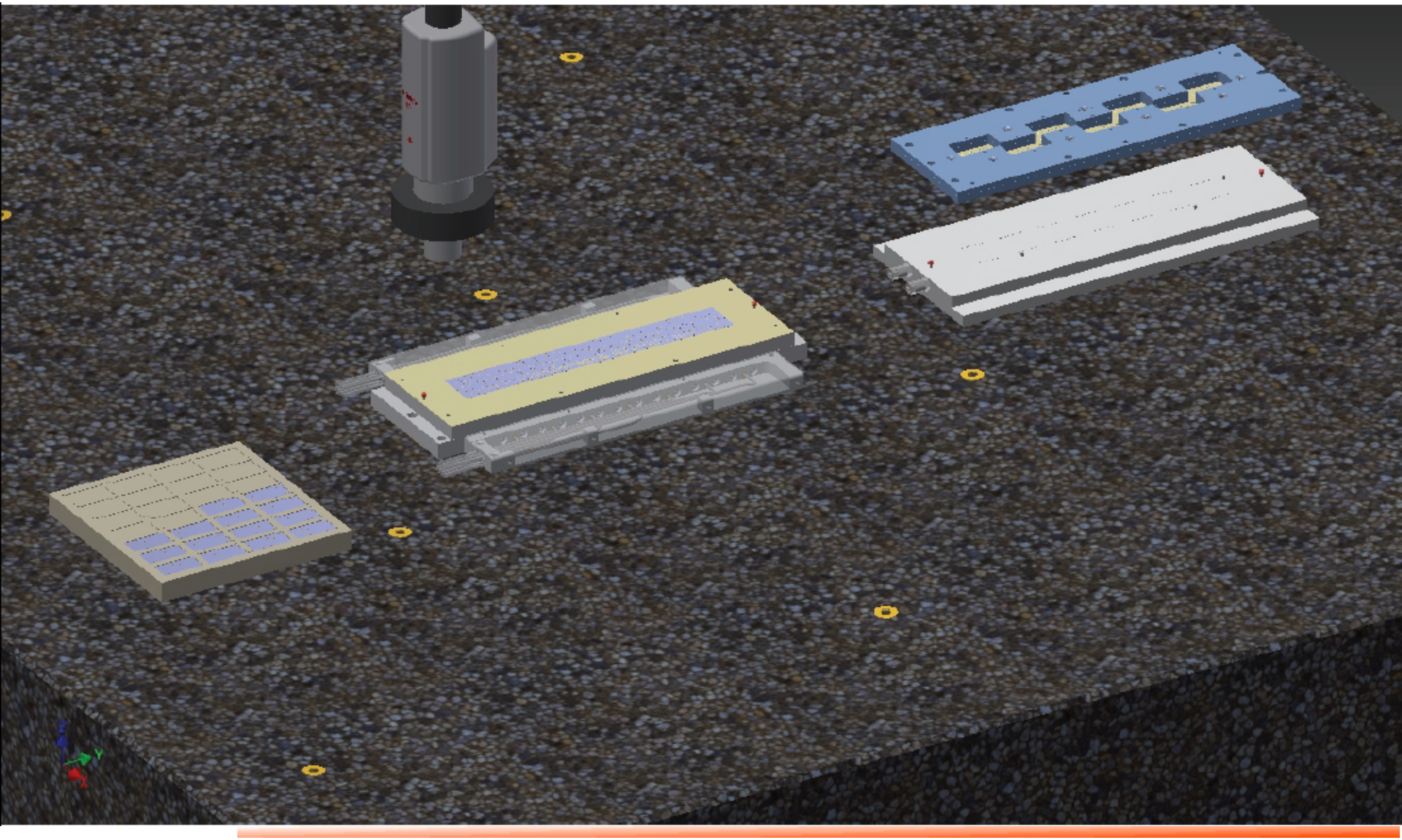

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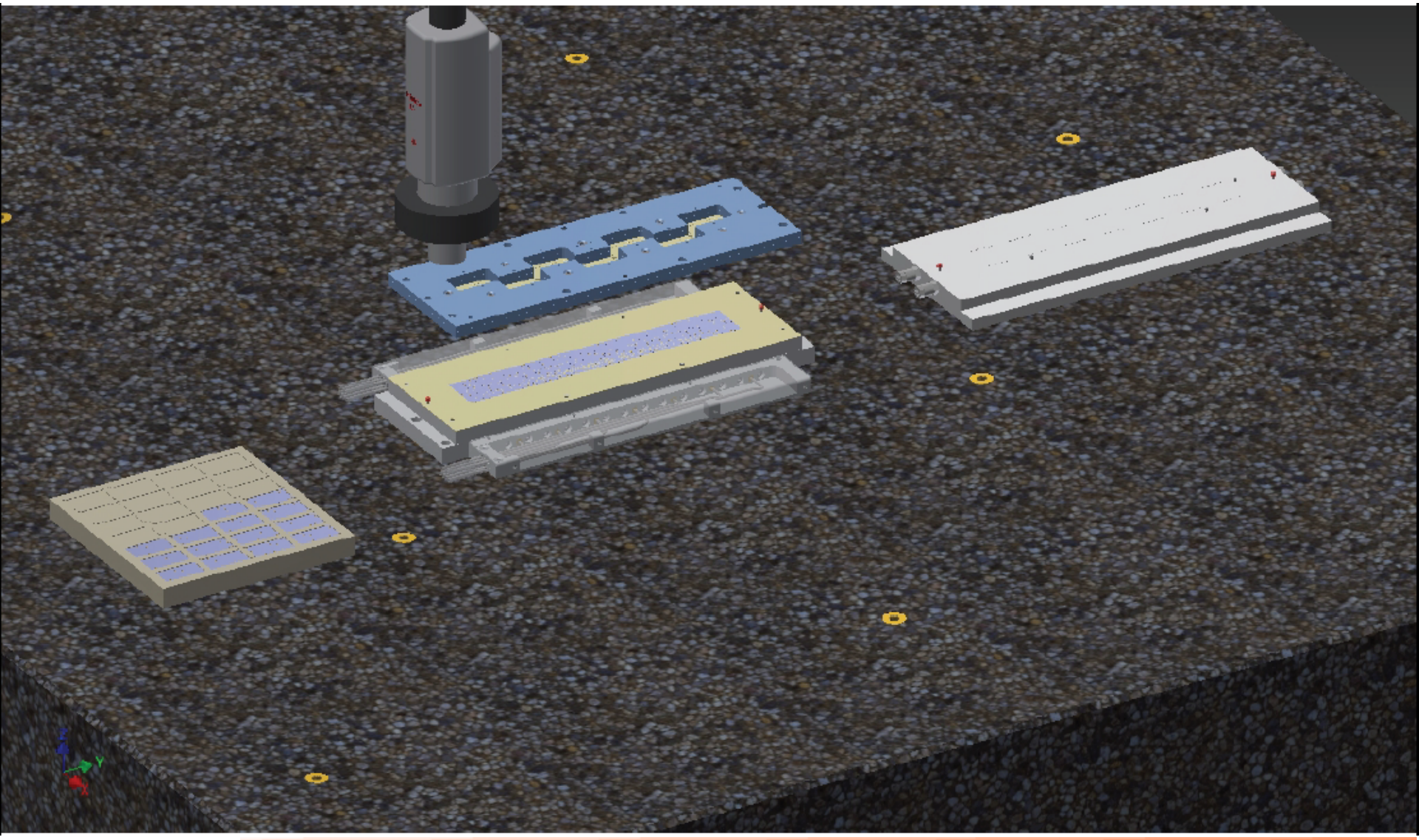
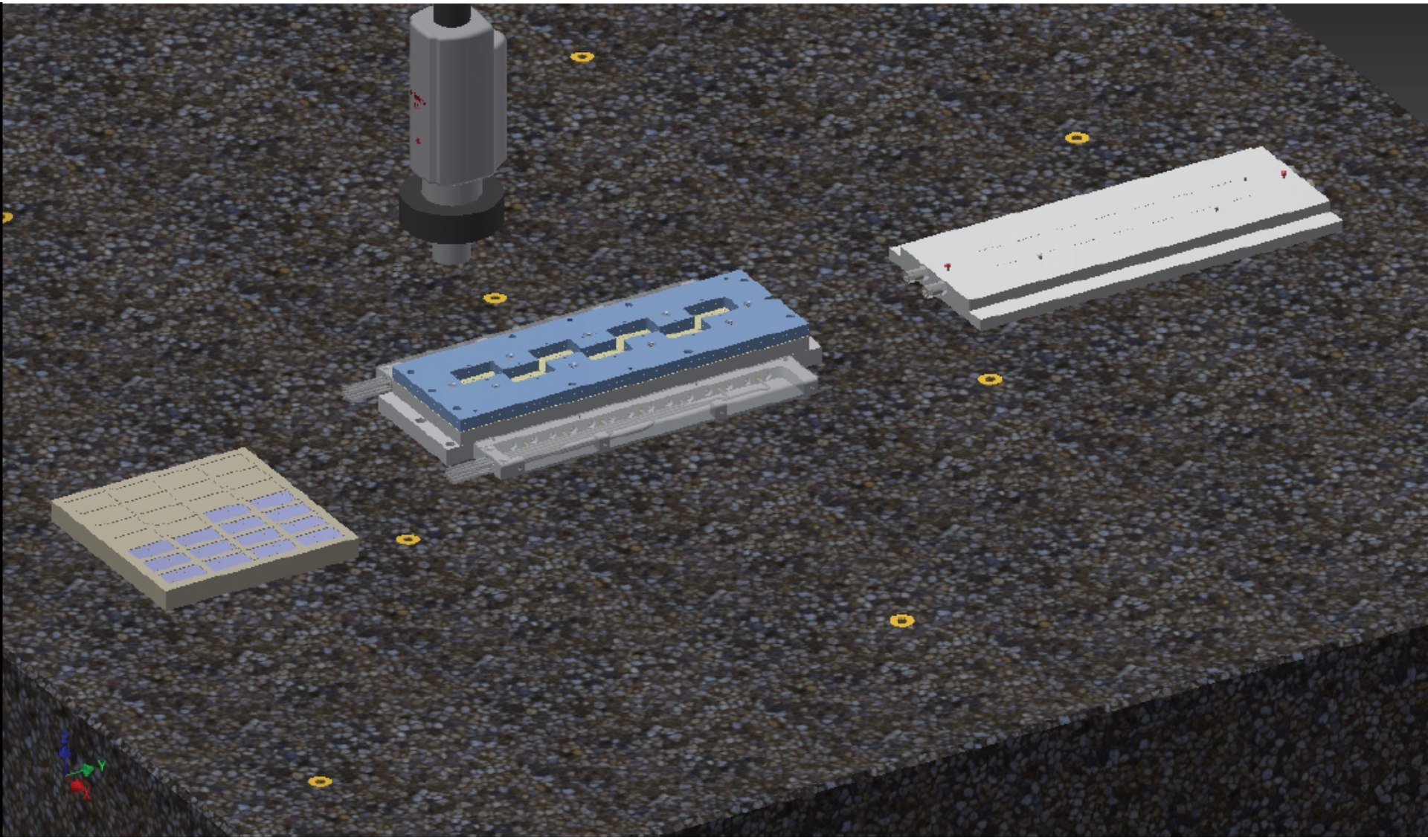


Concept Design of ALICE/ITS Module Assembly

Assembly cartoon with automatic module assembly machine:



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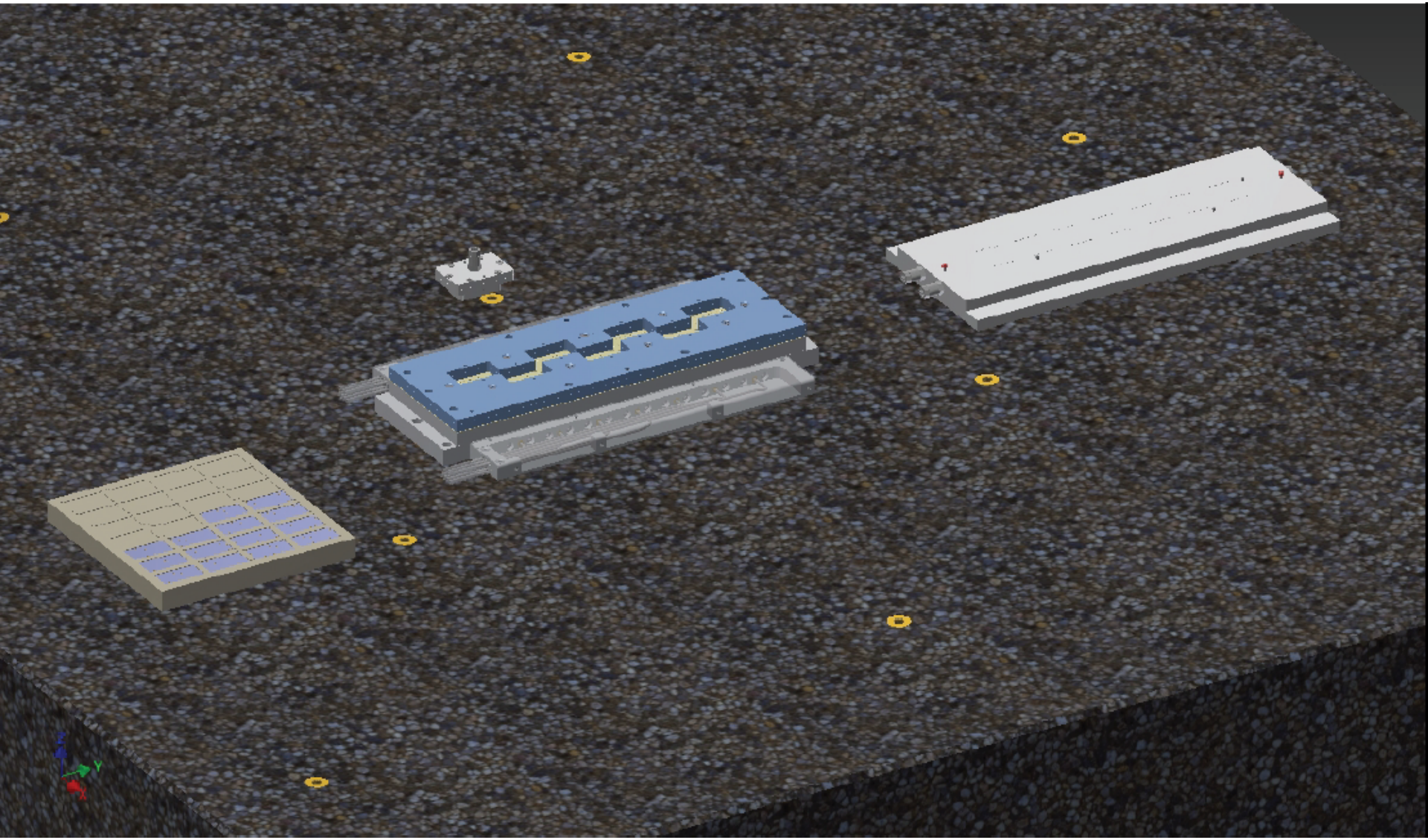

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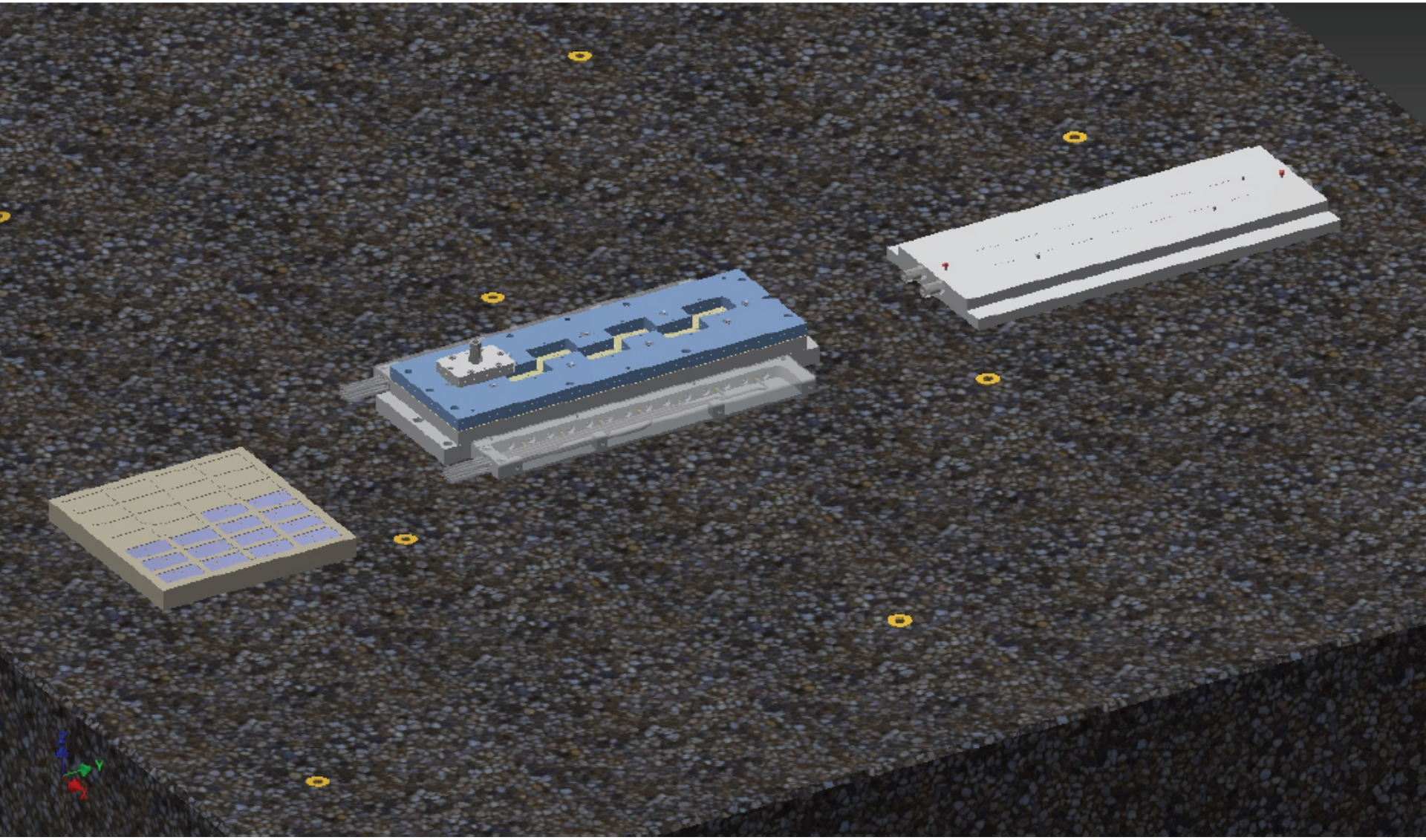

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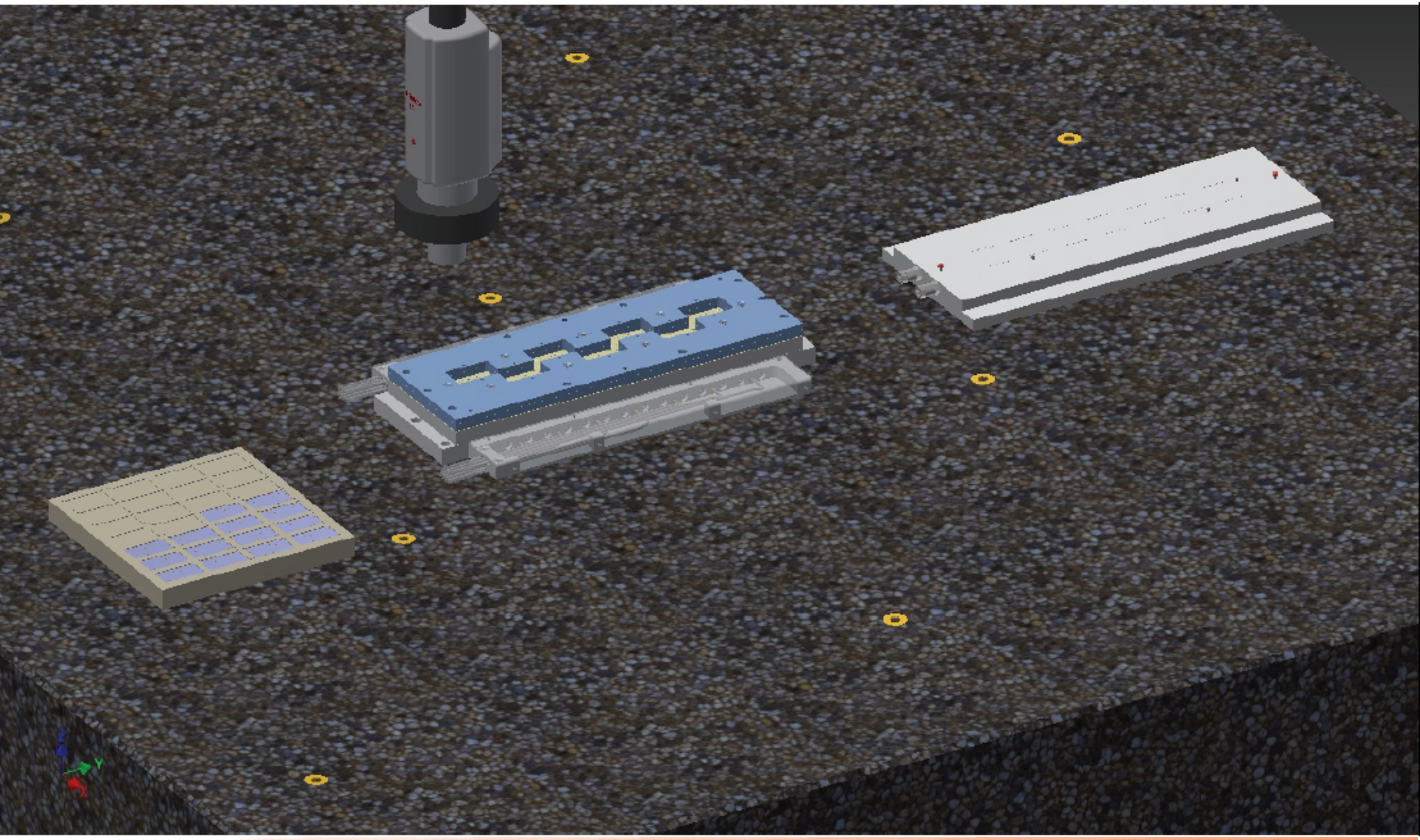

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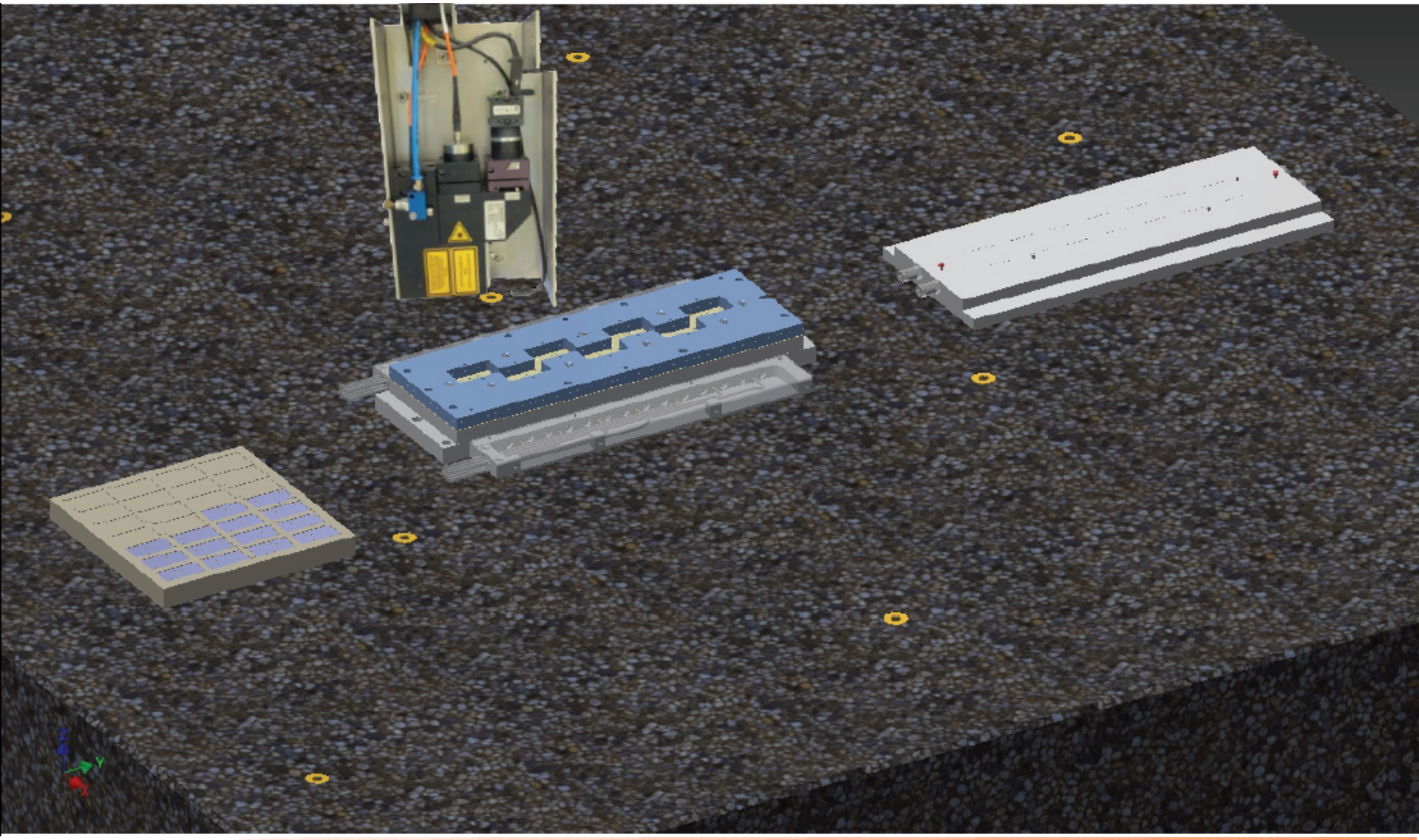

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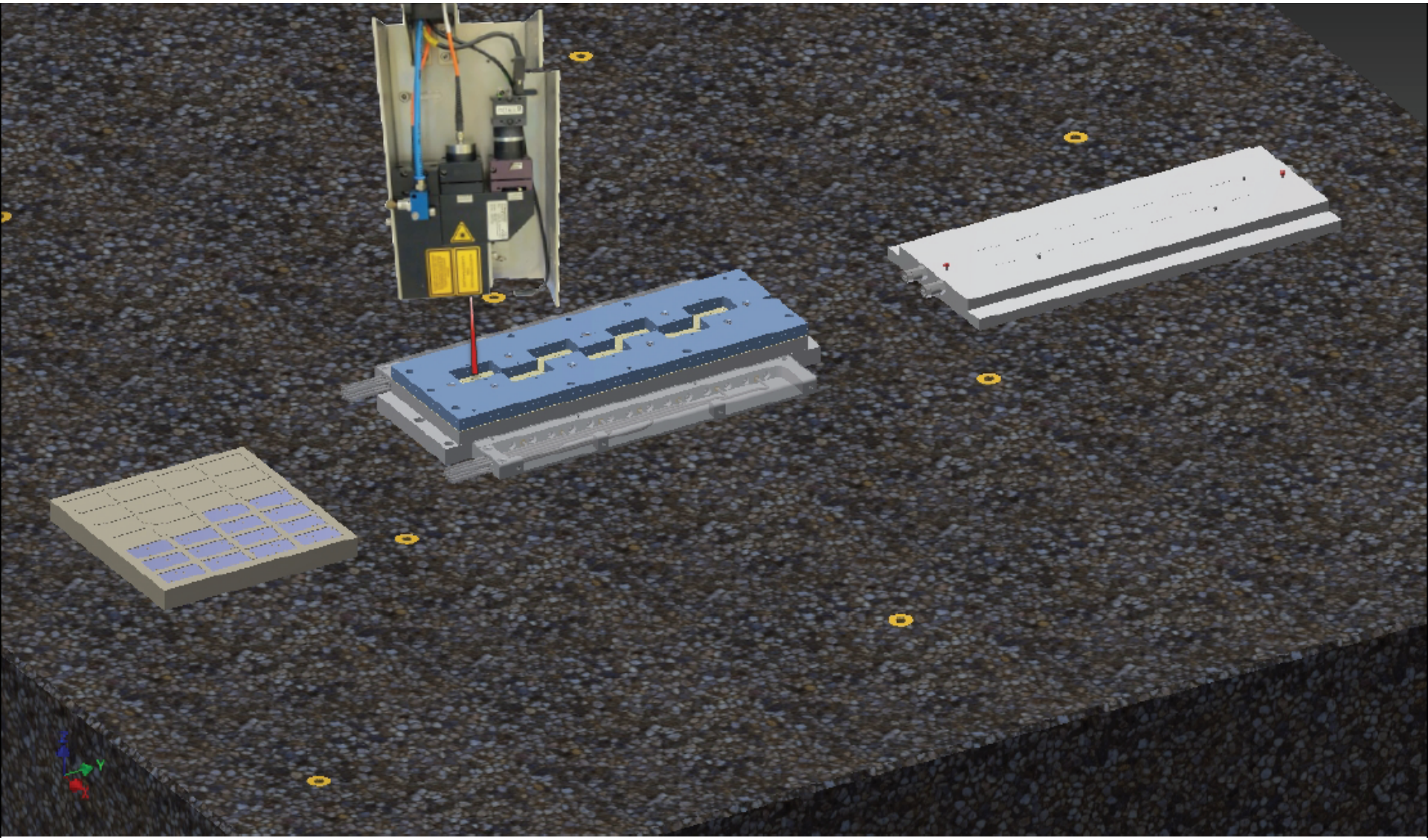

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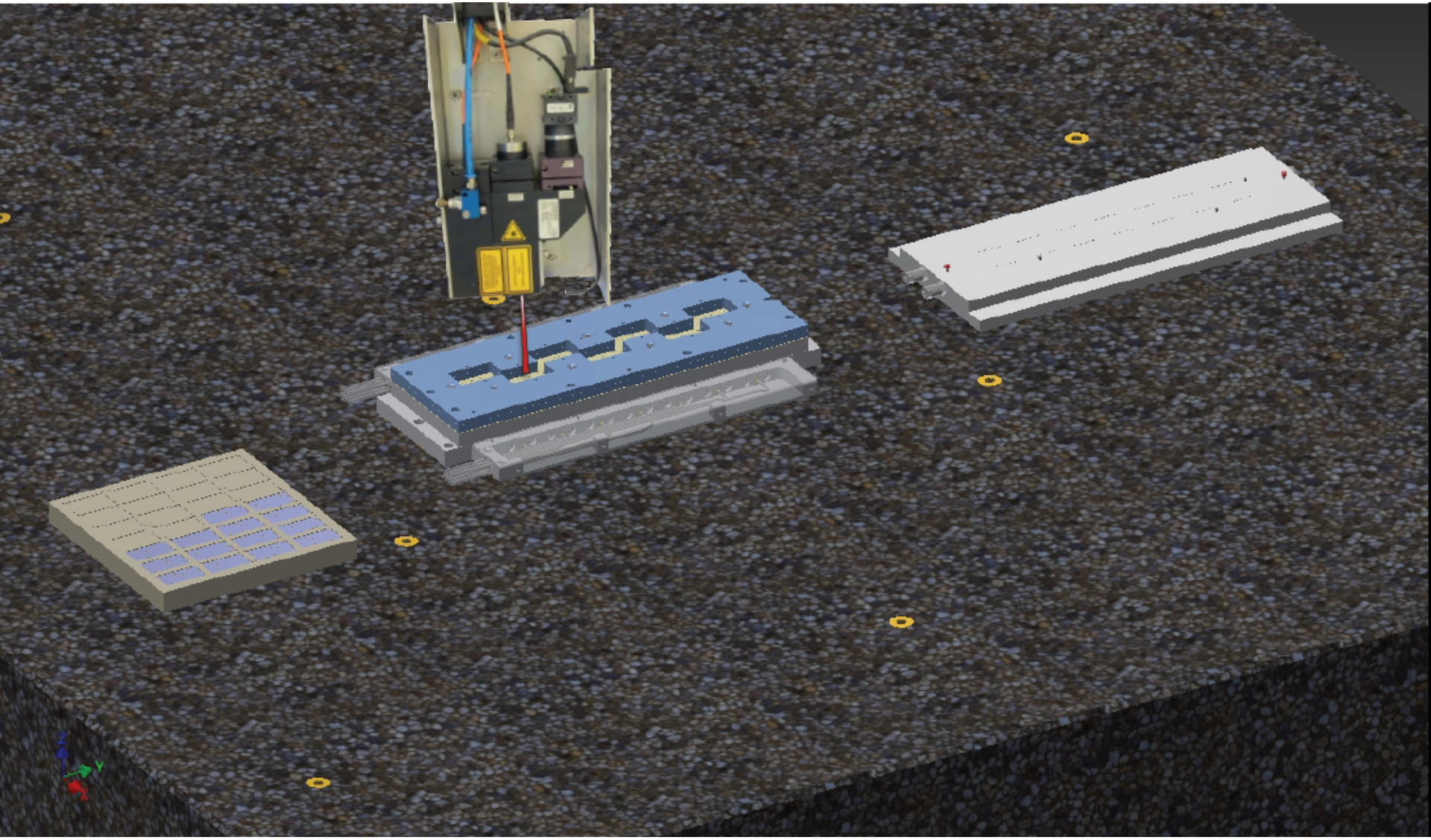


Concept Design of ALICE/ITS Module Assembly

Module test and shipment:

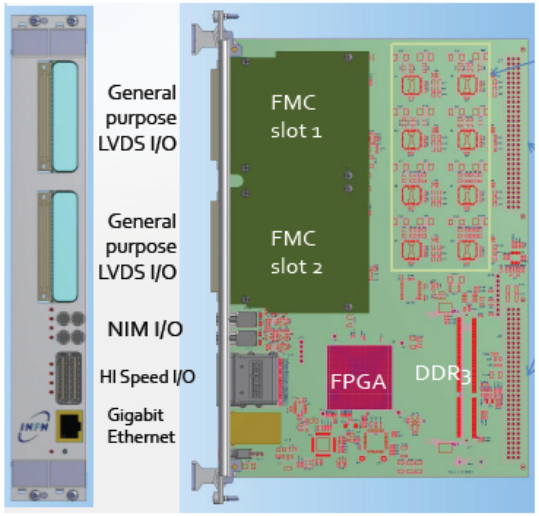
1. **Chips position** - measurements of chips position in the module with respect to reference markers, which will remain visible throughout the following construction and integration operations

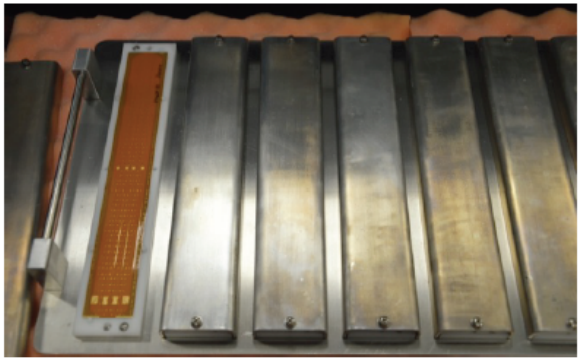
2. **Module characterization** - functional validation of modules according to a defined protocol

   - Test System developed by Bari group

3. **Module transport** - shipment of qualified modules to the Stave Construction Centers

   - Liverpool, LBNL, Turin and LNF, NIKHEF





V. Manzari - ALICE ITS upgrade, MFT and O² Asian Workshop 2014 @ Pusan –15 Dec '14

Concept Design of ALICE/ITS Module Assembly

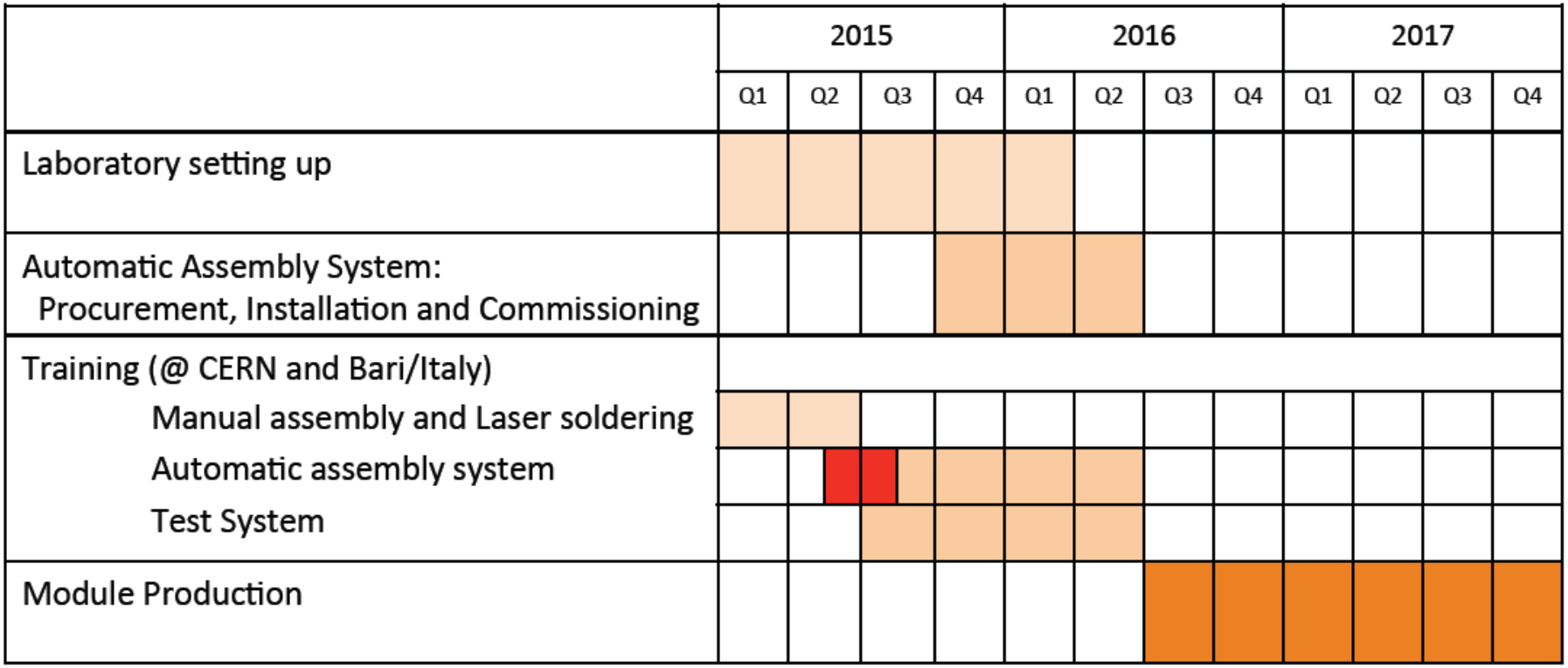
Construction site preparation:

- ☑ ~40 m^2 of a clean room class 100000
- ☑ Compressed air and nitrogen supplies
- ☑ Automatic assembly system
- ☑ Optical microscope for visual inspection, equipped with with image acquisition system
- ☑ Test bench equipped with readout and control system, cooling system and power supply systems
- ☑ Radioactive sources (typically ^{90}Sr, activity ~10 MBq)
- ☑ Storage cabinets (antistatic, desiccator) for components and assembled modules
- ☑ …

Concept Design of ALICE/ITS Module Assembly

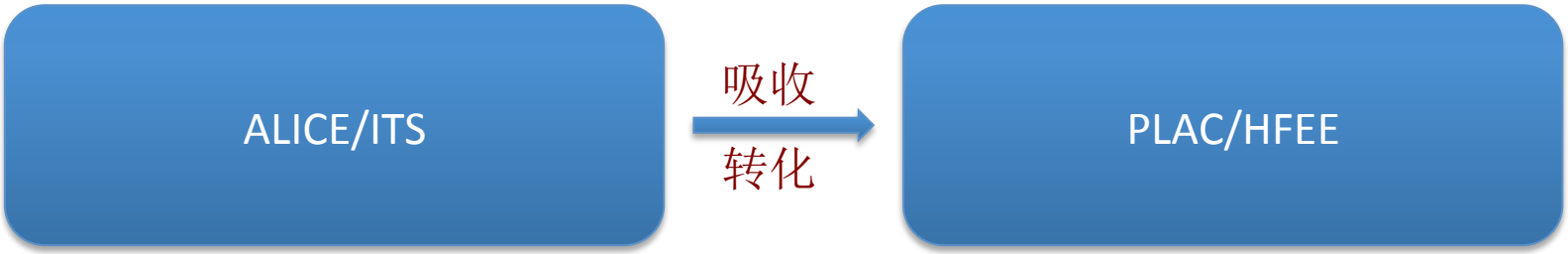
Timescale:

- Setting up of the infrastructures and training next year.
- Start module production mid 2016.



Conclusion and Outlook

Transfer what we learned from the ALICE/ITS module assembly to PLAC/HFEE applications?



Several automatic options can be done by mean of vision system:

- Automatic chip visual inspection
- Fully automatic chip placement/alignment
- Automatic FPC placement/alignment?
- Automatic placement of soldering balls
- Quality control of soldering joints by vision system
- Chip electrical test?

Conclusion and Outlook – We have a plan!

Thanks!